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U. S. DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES

PROGRESS IN BIOLOGICAL INQUIRIES 1935

By ELMER HIGGINS

ADMINISTRATIVE REPORT No. 26

U. S. DEPARTMENT OF COMMERCE
DANIEL C. ROPER, Secretary
BUREAU OF FISHERIES
FRANK T. BELL, Commissioner

Administrative Report No. 26

PROGRESS IN BIOLOGICAL INQUIRIES 1935

By ELMER HIGGINS

APPENDIX IV TO REPORT OF COMMISSIONER OF FISHERIES
FOR THE FISCAL YEAR 1936

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ADMINISTRATIVE REPORT SERIES

Since the beginning of the Administrative Report Series, considerable confusion has arisen concerning the system of numbering the separates composing it. Inasmuch as the Reports of the Divisions vary in order from year to year, many have found their designations as "Appendix No. I, II, III, or IV" very confusing. To relieve this, it has been decided to number them as "Administrative Report No. —." Inasmuch as 20 separates had already been printed in this series before starting the numbers, it was deemed advisable to begin the numbering with Administrative Report No. 21. Of course, numbers cannot be printed on those already off the press, but for the information of those who wish to know what the first 25 were, they are numbered for filing purposes as follows:

No. 1. Report, Commissioner of Fisheries, 1931.
No. 2. Alaska Fishery and Fur-Seal Industries, 1930.
No. 3. Fishery Industries of the United States, 1930.
No. 4. Progress in Biological Inquiries, 1930.
No. 5. Propagation and Distribution of Food Fishes, 1931.
No. 6. Report, Commissioner of Fisheries, 1932.
No. 7. Alaska Fishery and Fur-Seal Industries, 1931.
No. 8. Fishery Industries of the United States, 1931.
No. 9. Progress in Biological Inquiries, 1931.
No. 10. Propagation and Distribution of Food Fishes, 1932.
No. 11. Alaska Fishery and Fur-Seal Industries, 1932.
No. 12. Progress in Biological Inquiries, 1932.
No. 13. Fishery Industries of the United States, 1932.
No. 14. Propagation and Distribution of Food Fishes, 1933.
No. 15. Fishery Industries of the United States, 1933.
No. 16. Alaska Fishery and Fur-Seal Industries, 1933.
No. 17. Progress in Biological Inquiries, 1933.
No. 18. Propagation and Distribution of Food Fishes, 1934.
No. 19. Alaska Fishery and Fur-Seal Industries, 1934.
No. 20. Fishery Industries of the United States, 1934.
No. 21. Progress in Biological Inquiries, 1934.
No. 22. Propagation and Distribution of Food Fishes, 1935.
No. 23. Alaska Fishery and Fur-Seal Industries, 1935.
No. 24. Fishery Industries of the United States, 1935.
No. 25. Propagation and Distribution of Food Fishes, 1936.

Note that the last Commissioner's Report was for 1932. Since then its place has been taken by a reprint from the Report of the Secretary of Commerce under the title "Bureau of Fisheries." Inasmuch as it is no longer a Bureau publication, it is not numbered; but it will be supplied to any who request the Report of the Commissioner for any year since 1932.

PROGRESS IN BIOLOGICAL INQUIRIES, 1935[1]

By Elmer Higgins, Chief, Division of Scientific Inquiry

[With the collaboration of investigators]

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[1] Administrative Report No. 26, appendix IV to the Report of the U. S. Commissioner of Fisheries for 1936. Approved for publication May 17, 1937.

INTRODUCTION

Conserving our natural resources is no new concept of the twentieth century; it was a matter of concern in this country a hundred or more years ago. Today practically all people are agreed that it is a matter of common and vital necessity to the welfare of the country.

But while there is no longer a need for defending conservation, or even for justifying the existence of agencies for its wise application, there is constant need for re-defining it; for "conservation" is one of those flexible words that has been bent into many different meanings to suit many different purposes. The phrase, "conservation of fisheries", for example, has whatever connotation a person wishes to give to it.

To many people, perhaps even to most, it implies some form of prohibition. To some it means prohibiting all people from fishing, so that all fish may live their lives in the ocean and in the streams forever unmolested; to others, it means prohibiting only other people from fishing, so that they themselves can enjoy exclusive right to pursue their piscatorial pleasures without competition.

In the face of such confusion, then, what does the Bureau of Fisheries mean by conservation? It means precisely what a business organization does when it refers to a conservative financial policy. In other words, it is the practice of getting for the most people the greatest value from resources without impairing the capital—living off the income without cutting into the principal.

It is generally agreed that a business organization can neither formulate a conservative fiscal plan without a considerable background knowledge of business principles, nor can it maintain a continuous conservative policy without a constant study of current business conditions. Hence the need for economists, market specialists, accountants, etc. In the same way it is impossible for the Bureau of Fisheries to formulate a conservative plan for administering the fisheries without a background knowledge of biological principles, and impossible to carry out such a policy without a continuous current study of conditions affecting the fish. Hence the need for a permanent staff of aquatic biologists. The Division of Scientific Inquiry of the Bureau of Fisheries carries on such a continuous program; and this report sets forth briefly the results obtained during 1935. It must be clear from the following pages that the several researches here recounted are not short, completed studies, but long-term ones, for which this report represents but a small segment.

One of the most significant facts which is becoming ever more apparent is that the service which the Division of Scientific Inquiry offers cannot nearly meet the demand, for the service is considerably limited by the funds at hand. An investigation on a single fishery is seldom a one-man project, particularly when the species studied is widely distributed, when data must be gathered simultaneously from widely separated regions. In fact it is usually inadvisable even to attempt a serious one-man investigation on a large and important fishery. Consequently many species must remain unattended until resources are available to undertake proper studies on them. Even the current investigations have all been considerably

circumscribed during the past several years as a result of curtailed funds. Nevertheless, much progress has been made during 1935.

As our knowledge of the vast, continually changing network of factors influencing aquatic life increases from year to year, it becomes ever more possible to conserve the fisheries by management rather than by restriction. Thus, for the fresh water species throughout the country, much progress has been attained in making the inland waterways biologically more habitable and productive. This is being accomplished in two ways: first, by discovering sources of pollution and encouraging their elimination, usually with the friendly cooperation from owners of factories and mills bordering the waterways; second, by developing methods of improving the natural environment in streams so as to make them more productive of fish life.

The populations of fresh-water fishes have continued to be maintained and distributed by stocking from hatcheries. Current research in this field is devoted mostly to improving the breed of stock so as to obtain the highest fecundity and fertility; also to developing the most efficient feedstuffs so as to get the most fish per pound of feed. There is still an enormous amount of research to be done in the field of aquiculture, however, particularly with reference to the relation between environmental influences and population growth and decline.

As for the commercial fisheries, the most important work in this field has been the development of our knowledge concerning the causes of the great fluctuations in abundance which so deeply affect the fishing industry. The complicated interrelations between these fluctuations, the fishing intensity, the population abundance, and the birth and mortality rates continue to be the subject of intensive studies.

Another important phase of activity in the Division of Scientific Inquiry is concerned with the shellfish industry, particularly with respect to oysters. The most productive work in this field during 1935 has been the development of effective methods for curbing the destructive enemies of the oyster, namely, the starfish and drills. As was pointed out in the 1934 report, however, there still remains a vast amount of work to be done in the field of oyster culture and oyster farming.

COOPERATION

An effective program of conservation through management is impossible without the wholehearted cooperation of all the people directly or indirectly affected by such a program. It is gratifying, therefore, that States, other Federal departments, and private industry are working with the Bureau of Fisheries more than ever in carrying on scientific fishery investigations. But it must be pointed out that even this much cooperation is not enough. It is true that the provision of biologists, of laboratory facilities, of boats, of test streams, of moral support goes a long way toward achieving the scientific knowledge that is needed for intelligent fishery management; but this knowledge will be of little use until neighboring States cooperate with each other in formulating, passing, and enforcing effective and consistent conservation legislation. That is work of the States that remains to be done in order to make these scientific investigations useful.

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NORTH AND MIDDLE ATLANTIC FISHERY INVESTIGATIONS

O. E. Sette, *in charge*

With an upturn of fish prices accompanying the return of meat prices to nearly normal in 1935, activity in the fishing business has reawakened. Trawlers that had been tied up in previous years saw increasing activity, and new ones are being built. The mackerel fleet, which had been experimenting with curtailment of production, resumed unrestricted fishing and landed the largest catch of the present century. The fleet of smaller boats has seen additions to its numbers, and increases in efficiency through new and larger motor installations. A further evidence of increased activity was the development during 1935 of large-scale commercial use of the rosefish. This species hitherto was practically unused but now is being marketed on a large scale, landings totaling 17,000,000 pounds in 1935 as compared with 2,000,000 pounds during the previous year. Similar development is taking place with respect to sea robins caught in the winter trawl fishery off the Virginia Capes.

As to the condition of the resources, the haddock fishery continues to be most productive on the grounds lying off Nova Scotia where the fishery has been concentrated during recent years. On the nearer grounds such as Georges Bank and South Channel, the yield continues low, and, though somewhat improved over the previous year, the level of abundance is still far below that of 1920. Indications are strong that general adoption of the "savings gear"[2] developed by the haddock investigators would bring about a more decided improvement in future yield. Mackerel is at a high level of abundance mainly as a result of the unusually productive spawning seasons of 1930, 1931, and 1933. Among the shore fishes of the Middle Atlantic coast scup and butterfish are maintaining their productivity under the present amount of fishing but squeteague, especially the younger and smaller sizes, undoubtedly are being subjected to more intense fishing than is consistent with obtaining the maximum yield.

[2] Modifications in gear to curtail the destruction of undersized fish in otter trawling, by William C. Herrington. Investigational Report No. 24, U. S. Bur. of Fish.

It is to be regretted that a more complete survey of the condition of the fishery resources is not possible. Limitations of funds and personnel are such that only a few of the important species can be studied. The cod fishery is being more thoroughly fished as the haddock supply has diminished, and during the last several years the portion of the population south of Cape Cod has become notably sparce. Whether this is owing to natural causes or to undue exploitation is unknown. The yield of flounders is diminishing year by year in spite of greater utilization of those that formerly were considered "trash." It is unknown whether this decline in productivity might not have been avoided or might not still be halted; nor is it known whether restrictive legislation on flounder fishing now in force in some States is beneficial. What should be done to halt the declining lobster catch is a further question. In fact, each major fishery is in need of study.

Even the species that are being studied cannot be given the attention that they deserve. There are pressing needs for more adequate treatment in each field. In the Middle Atlantic section there should be experiments to devise methods of fishing that would save young fish from destruction. The mackerel investigation needs facilities for work at sea to further unravel the mystery of spawning failures so as to foresee the crop of yearling mackerel (tinkers). The haddock work also needs sea-going equipment and, further, should have clerical assistance to keep the statistical analyses up to date, for it is by these means only that the conditions of the resource may be known.

It is obvious from the nature of the problems facing the fishery investigator, that accurate and detailed statistical information is essential. For the most part, it is necessary to collect special series for each biological study, but the regularly collected, total-yield statistics are also needed. To render them more suitable for biological purposes, a revision of the method of reporting landings at the principal New England ports, with special reference to area of origin, was worked out in conjunction with the Division of Fishery Industries and will be put into effect in the ensuing year. The areas were delineated in collaboration with members of the North American Council on Fishery Investigations, and it is anticipated that eventually the statistics of all countries participating in the American North Atlantic fisheries may be reported according to a uniform scheme of statistical areas.

Before passing on to the details of results, it is appropriate to acknowledge gratefully the courtesy of Harvard University in providing the staff with quarters in its Biological Laboratories; the cooperation of the Woods Hole Oceanographic Institution, especially in assigning its research vessel *Atlantis* to certain haddock trawling cruises; and the personal interest of Prof. Henry B. Bigelow in advising the staff on many phases of the work. It is a pleasure also to acknowledge the kindness of fishermen and fish dealers in permitting the use of their records and in other ways cooperating in the work.

Two subjects, cod and flounder, considered in separate sections in previous annual reports, are not so treated herein. In both instances the material consists of returns from taggings done in years prior to 1933. Although a few returns continue to be reported, they do

not affect the conclusions previously derived from these experiments. William C. Schroeder, formerly of the staff of the United States Bureau of Fisheries but now connected with the Woods Hole Oceanographic Institution, carried on the cod investigations formerly and still maintains his interest in the subject. To supplement the evidence received from tagging, he is making a study of the structure of scales collected from tagged individuals. Results from this research may be expected at a future date.

HADDOCK

The total quantity of haddock landed at principal New England ports in 1935 reached nearly 157,000,000 pounds. (This includes all United States' landings except relatively small amounts landed at minor ports.) This was 23 percent greater than the catch of the previous year; in fact, the largest since 1930, and the fourth largest in the history of the fishery. As in 1934, the greater part came from the fishing banks lying off the Nova Scotian coast (Sable Island, Banquereau, Browns, and La Have); landings from this area increasing from about 82,000,000 pounds in 1934 to 91,000,000 pounds in 1935. Georges Bank continued in a minor role, although the catch increased from about 39,000,000 pounds in 1934 to 63,000,000 pounds in 1935. This was 40 percent of the total haddock catch, whereas in earlier years Georges averaged nearly 80 percent of the total.

One of the first objectives of the program of investigation laid down in 1930 was to obtain a sound understanding of changes in the haddock catch such as occurred during 1935. From this, the program was directed toward the determination of the productivity of the fishery at various levels of fishing intensity in order to make possible the development of a plan of rational exploitation that would produce a maximum permanent yield at a reasonable cost of production. This program was in line with the general theories of fisheries investigations developed by Dr. William F. Thompson, director of investigations, International Fisheries Commission, who has affected materially the trend of the haddock work through earlier association with some of the investigation's personnel.

Although realization of the above objective requires a longer period of observation and more thorough analysis than has been possible with present personnel and facilities, there has been considerable progress along the lines of study described in previous annual reports. This includes particularly the collection and analysis of commercial catch records to obtain a measure of changes in abundance; and the study of extensive haddock length-frequency and scale samples to determine growth rate, mass movements, and the age and size composition of the population. The work has continued under the direction of W. C. Herrington assisted by J. R. Webster. Limitation of funds and personnel restricted field work mainly to the Boston Fish Pier where vessel interviews regularly provided information as to fishing time, position, and other relevant data for all haddock trips. Field observations included 2,620 interviews, 66,000 length measurements, and 4,200 scale samples. F. E. Firth handled most of the fish-pier work during the winter. Temporary personnel was employed during the summer while Mr. Firth was assisting in the

mackerel investigation. In addition to the field work at the fish pier, two trawling trips were made on the *Atlantis* to obtain material for the study of the abundance, distribution, and growth of 1-, 2-, and 3-year-old haddock which, being below marketable size, cannot be obtained from the commercial catch.

Georges Bank and adjacent areas.—As stated in the 1934 annual report, the success of the fishery on Georges Bank during any year, that is, the return for a given unit of fishing effort, is primarily dependent on two factors: (1) The rate at which the commercial stock declines as the result of catch and natural mortality. (2) The contribution to the commercial stock from the young haddock spawned 3 years earlier. There can be no sustained improvement in the catch except through the growth to commercial size of a large group of young haddock. Mass migrations do not appear to be an important factor; at least, they have not been since our detailed observations began.

A feature of the last 4 years has been the appearance of 3 fair year classes in the commercial catch on Georges Bank. These classes were spawned in 1929, 1931, and 1932. Of these, the 1929 class was the best and served to increase the fishermen's catch considerably in 1932. The 1931 and 1932 classes were less successful, and under a fishing intensity such as prevailed on Georges in 1927–33, hardly would have maintained the level of the fishery in 1934 and 1935. However, during these years a large portion of the fishing fleet was diverted to the Nova Scotian banks as a result of poor fishing on Georges and improved catches elsewhere. Hence, the fishing intensity on Georges decreased to less than half that of 1933 and earlier. With this lessened strain, the Georges haddock stock has increased for 2 successive years, the first 8 months of 1935 providing an average daily trawler catch about 30 percent better than the same period in 1933.

The moderate improvement in the fishery on Georges during the past 2 years has been encouraging, although the present population is far below the level prevailing in the years prior to 1930; and partial recovery occurred only with a greatly reduced fishing intensity.

The trend of the Georges Bank haddock fishery in 1936 depends on two elements now but qualitatively known. First, the abundance of the 1933 class which reaches commercial size in the winter of 1935–36. Second, the distribution of the trawling fleet, i e., the amount of fishing effort that will be expended on this bank in 1936. The first element—abundance of the 1933 class—cannot be evaluated until later in the year when it has been possible to analyze data from the winter fishery. However, cursory examination of incomplete records indicates that it may approximately equal the classes of 1931 and 1932. The second element—distribution of fishing effort—could be estimated if the relative abundance of fish on Georges and Nova Scotian banks were known. This too can be but roughly estimated until the results of the winter fishery can be analyzed. In view of a probable decrease in the catch per day on the Nova Scotian banks and an increase on Georges, one may expect a larger percentage of fishing effort to be concentrated on Georges Bank in 1936. This increased strain will, to some extent, counteract the expected increase

from the 1933 haddock year class. Therefore, the final 1936 results should be a total Georges Bank haddock catch considerably greater, and an average daily trawler catch about the same or a little better than in 1935.

Nova Scotian Banks.—The haddock catch on the Nova Scotian banks in 1935 totaled 91,000,000 pounds, an 11-percent increase over 1934, resulting primarily from augmented fishing effort. During the first 8 months of the year the average daily catch per trawler was about the same in 1935 as in 1934, indicating that the fishery apparently has not yet made serious inroads into the stock of marketable haddock. However, the catch has been maintained partly as the result of the extension of the fishery to the eastward on Quereau.

Our knowledge of the haddock population off the Nova Scotian coast is less complete than for that on Georges Bank, but it appears that the success of the fishery depends on the same factors, i. e., mortality rate and the contribution to the commercial stock from the younger year classes. If this be true, the 1936 fishery should be somewhat below the 1935 level unless the 1932 year class (which will begin to reach commercial size in the summer of 1936) is relatively abundant.

There have been some indications that insofar as the spring season (that is, the spawning period) is concerned, a new year class does not exert a maximum effect on the commercial catch during the first year its members reach marketable size. Thus, although the 1929 class reached marketable size in the summer and fall of 1933, the catch per day in the following spring (1934) was not so great as in the spring of 1935. But during the summer of 1934 the catch was considerably greater than during the summer of the following year.

Requirements of the investigation.—In the above discussion the trend of the fishery has been considered mainly in qualitative terms. The most pressing requirement now is a more complete analysis of material so that the various elements determining the success of the fishery can be studied quantitatively. Only then can we accurately describe the causes of fluctuations in abundance, or predict the effect of measures designed to improve the catch. Length-frequency and scale data particularly need more thorough study which limitations of time and personnel so far have made impossible. The haddock fishery is pursued on a large scale throughout the year, and extends over a wide area from Nantucket Shoals to the Grand Bank of Newfoundland. Consequently, an extensive series of data is required to follow the fishery, and there is no slack season in which to bring the analysis up to date.

Some special problems could not be given sufficient attention during the past year. An accurate measure of the annual variations in haddock abundance is of fundamental importance to this investigation. In general, these variations are shown by the availability of haddock to the fishermen, which is measured by the average daily catch per trawler. But a change in the efficiency of the fishing boats whose catches are analyzed will distort this measure of abundance. Such a change took place during the years 1929–31 when the fleet changed over from the ordinary otter trawl to V. D. or semi-V. D. gear. An analysis not yet completed indicates that this increased the efficiency of the fleet by at least 25 to 30 percent.

Another distortion appeared in our measure of haddock abundance on Georges Bank when in 1934 the fleet of large trawlers shifted a large part of their fishing activity to the Nova Scotian banks. Georges was fished only when the yield was particularly good; therefore, the catches of these boats give too high an average for 1934 and 1935. The extent of this distortion must be determined before quantitative interpretation of the data is possible.

If available knowledge is to be used to prepare for the fishing industry a reliable forecast of the trend of the fishery for one or more years in advance, one other type of datum is absolutely necessary. This is an annual evaluation of the abundance of young haddock in year classes below marketable size. These data also would enable us to obtain a measure of the natural mortality rate of young haddock. To secure such data requires considerable trawling with special gear. No extensive work of this kind has been possible due to lack of vessel facilities, but during the past year some exploratory work was done on the *Atlantis*, made available by courtesy of the Woods Hole Oceanographic Institution. Only qualitative conclusions are possible from the material so far collected. Quantitative results would require the use of a vessel equipped for regular trawling and a number of comprehensive cruises each year.

Hydrography.—During the years 1931–34, hydrographic data were collected and drift bottles released over an area covering Georges Bank and Browns Bank. The cruises were made during the spring of the year to obtain data for the study of ocean currents and their effect on the drift of haddock eggs and larvae spawned in this region. Although no field work of this kind was done in 1935, 25 drift bottles were received from the April 1934 experiment and two from the experiment of June 1933. From the 1934 experiment there now is a total of 91 returns from 629 released. Of these, 16 percent came from west and south of Cape Cod, 42 percent from the Gulf of Maine, 13 percent from the Nova Scotian and Newfoundland coast, and 24 percent from Europe. One-half of the 1934 drift bottles were painted a brilliant yellow and released alternately with clear glass bottles. A red card was enclosed in the unpainted bottle. At the end of 1935 returns from painted bottles were 27 percent higher than from unpainted ones.

Although attainment of the general objectives of the investigation remains for the future, certain lines of study have already yielded results of immediate practical importance. Extensive field work in 1931–32 showed that the trawling fleet annually destroys great numbers of small haddock below marketable size. This number varies according to the abundance of young fish on the banks and the number of boats fishing. In 1931 on Georges Bank it reached an estimated total of more than 60,000,000 baby haddock compared to a catch of not much more than 30,000,000 of marketable size. Since then the destruction has been less, not because the fishery has been less destructive but because baby haddock have been less numerous and the fishing intensity has been reduced by the diversion to the Nova Scotian banks of a considerable part of fishing operation. Nevertheless, the situation continues wherein every brood of young fish is subject to a period of extensive destruction during its early years before it reaches marketable size. This loss of young haddock

serves to increase the drain on the fishery to nearly the same extent as the capture of equal numbers of marketable haddock. In other words, this destruction in some years doubles and trebles the strain on the fish population, and on the average must form a very considerable part of the fishing mortality. There also has been an increasing trend toward the marketing of smaller haddock, many averaging little more than half a pound in weight. Given another year on Georges Bank, these fish would treble in weight while in 2 years they would weigh nearly five times as much and be of more value per pound.

Recommendations.—There appear to be four possible measures that would decrease the destruction of undersized haddock. These are closed seasons, closed areas, minimum market size, and minimum mesh size. Of these, the most effective and practical are a minimum mesh size and a minimum market size. In 1931 and 1932 a practical type of "savings gear" for the New England otter-trawl fishery was developed through an extensive series of experiments. A report on this work was published in 1935 recommending a minimum mesh size of 4¾ inches for use in all otter trawls. So far, little action has resulted from this recommendation in spite of the clear evidence in its favor.

A more popular description of the savings-gear work and of the importance of saving undersized fish, is in preparation for use as a fisheries circular. It is hoped that this will find a wider audience because of its less technical nature. Certainly, convincing the trawler operators and fishermen of the importance of protecting small fish is a prelude to any effective action.

Savings gear experiments have demonstrated a practical method by which the strain on a fish population can be decreased without the application of any restriction such as closed seasons or closed areas. Adjustment of mesh size to reduce the destruction of small unmarketable haddock certainly will reduce the strain without curbing the fishery. Furthermore, in cases where over-exploitation is reducing a fish population to uneconomic levels of abundance, adoption by the operators of a suitable mesh size should prove more effective in conserving the fishery than restrictions such as closed seasons or closed areas. Once growth rates and natural mortality rates have been established, it appears possible to determine the average fish size that will produce a maximum catch over a period of years without depleting the population. Then, by proper adjustment of the selective gear (mesh size in the case of the otter-trawl fishery), it should be possible to eliminate from the commercial catch a large proportion of the young, rapidly growing fish below this size. If this permits the survival of an adequate spawning stock, it may well be that such protection would be sufficient to prevent real depletion, irrespective of the intensity of the fishery. In the case of the North Atlantic haddock, we do not yet have such data as will permit the determination of this optimum size, but there is some indication that on the Nova Scotia banks it may be not far from the present accepted minimum commercial size.

MACKEREL

With the resumption of unrestricted fishing in 1935 the offshore fleet landed 53,000,000 pounds of mackerel, the largest catch of the

present century. Though a record catch, it is not much larger than others of recent years, for the mackerel population has been in a phase of high abundance during the last 10 years. The average annual catch for the decade ending with 1935 was 41,000,000 pounds, which is a marked increase over the previous decade with its average of 17,000,000 pounds, and in even more striking contrast with the decade ending with 1915 when the average was only 11,000,000 pounds. But even the present high level is not to be regarded as the apex of yield for in the decade ending with 1885, the average was 80,000,000 pounds, an amazing yield compared with present experience.

This brings into high relief the dominating feature of the mackeral resource—its extreme fluctuations in yields. To find the causes of these fluctuations and to discover means of turning this knowledge to economic advantage has been the purpose of the research on the mackerel fishery.

The studies which have been under way since 1925 have proven that the changes in yield are mainly caused by changes in abundance of mackerel, and only secondarily by variations in the rate of fishing or by extensive migrations of the fish. Further, it has been learned that the changes in abundance are due to great differences from one year to another in the numbers of young mackerel that survive to commercial size.

The present state of knowledge has been arrived at by the study of changes in the mackerel population by the sampling method. In 1935, as in previous years, this work has been under the direction of Oscar E. Sette, who was assisted in the field work by Frank E. Firth. Basic data collected were the statistics on daily landings of each vessel of the fleet, information from interviews with fishermen covering 1,371 of the 2,560 fares landed, and samples of 51,347 mackerel from 752 different catches. For purposes of determining age composition of the population, length measurements were taken of all samples. In addition, meristic characters such a fin spines and rays were measured on 1,169 individuals to serve as an indication of subdivisions or "races" in the population.

In the laboratory, time available after meeting current demands was spent in organizing for publication the results of 10 years' accumulation of data. This has involved refinement of the method of statistical treatment to measure abundance, development of means of treating length measurements of mackerel to provide suitable accurate age-composition estimates, and their application to the 10-year series. In addition, some progress was made in analysis of tow-net collections of eggs and larvae of the season of 1932. That season is now known to have contributed but few recruits to the stock and therefore must have been one of high "infant mortality." The most commonly accepted theory of the cause of such year-class failures has been that the newly-hatched young do not survive the yolk-sac stage. But the data of 1932 do not indicate an appreciably higher rate of mortality at this supposedly critical point than during subsequent stages. If this is confirmed by examination of other years' data, it will have important bearing on further search for the causes of failures in year classes—a phenomenon occuring not only in the mackerel but in many important food fishes. This problem has been a perplexing one to the students of fisheries biology, and

has not yet been satisfactorily explained in the case of any marine species.

While each year's study has added considerable knowledge to the store needed for rational exploitation of the mackerel fishery, the problem is so complex that the goal is yet far from attainment.

With fluctuations the dominant feature in this resource and with their causes due to natural conditions not subject to control by man, the problem of proper utilization depends on making the most of what nature provides. There are at least two problems involved in providing the information needed to bring about such wise use. Most obviously useful is to find means whereby the fluctuations may be anticipated so that fishing and distribution may be adjusted to the rapidly changing volume of supply. The other is to find out what age (or size) of mackerel may best be fished in order to get the most of each year class, and to find means of encouraging the methods of fishing that, on the average, will take such sizes.

Considerable progress has been made in developing means of foreseeing the changes in the supply of mackerel. Predictions have been prepared and, except in the case of 1935, published at the beginning of each season since 1928. Within their scope, these predictions have been encouragingly close to the mark but their utilization by the industry has not been extensive. This appears to be due to their being restricted to estimates of only the larger sizes of mackerel, and further limited to estimates of the probable results of the season as a whole rather than its separate parts. Our present inability to predict abundance of small mackerel (under one pound) is serious because frequently a large portion of the catch consists of these small mackerel, known as "tinkers" to the trade, and their abundance often makes the difference between a good and bad season. Similarly, the changes in abundance within the season often are more important than the total catch for the year because the principal means of adjustment is to freeze or process surplus fish; and to adjust such operations to the season's run it is necessary to know when the surplus will be greatest. For instance, dealers are loath to freeze fish early in the season even when the market is full and prices low, for fear that later the oversupply may be still greater and prices still lower.

To be able to predict abundance of tinkers and thus round out the forecast service requires that their abundance be measured during the first year of life, which in turn requires special observations at sea that can be made only by means of a research ship. Work on this phase had progressed to a promising stage, but ceased in 1932 when the *Albatross II* was decommissioned for lack of operating funds. Although observation in this field has been discontinued, the analysis of results is still under way (as above mentioned) and will have important bearing on any future work in this field.

The problem of predicting the "run" at various parts of the season is amenable to solution. There are indications that there exist, within the mackerel population, different types whose habit is to appear fairly regularly at certain times and places, depending on their age. These peculiarities were taken into account in the prediction for the 1935 season and pointed toward an unusually large run in the offing of southern New England in the spring season

tapering off by the middle or end of August. This proved to be the case, experience differing from prediction only to the extent of the disappearance of these fish about 1 week later than the predicted date. As for the remainder of the season, no prediction was ventured, for tinker mackerel were likely to dominate that portion of the season and there was no means of foreseeing the abundance of this category.

More important than predictions, in the long run, is the determination of the best stage in the life history for commercial exploitation. Generally speaking it pays to let fish "grow up" before catching them, for the small and young grow very fast, and the gain from added weight far exceeds the loss from mortality. But in the case of the mackerel it is not a matter of simply balancing growth increase against mortality loss. The population appears to contain two types (perhaps races) of mackerel. One type, which for convenience has been designated "persistent", has an apparent mortality (decline in catch per unit of fishing effort) in the neighborhood of 20 percent; the other, termed "transitory", has one of 70 or 80 percent.[3]

Other peculiarities of the two types such as time and place of occurrence, growth rates, etc., lead one to believe that the differences in apparent mortality are not merely chance variations but are linked with the habits of the fish. If the high apparent mortality of the transitory type is the result of fishing out too large a percentage per annum because they school inshore and are readily accessible to the fishermen, then it would pay to lessen the fishery strain; but if, on the other hand, the mortality is apparent rather than real, and disappearance is due to changes in habits of the mackerel as they grow older, such as a tendency to swim deeper, or a tendency to scatter rather than to school, or even to migrate to distant waters, then it would pay to take them while they are easy to catch even though they be small. Such little evidence as is available favors the latter view; but to make certain it is necessary to perform large-scale tagging operations and perhaps extend other field observations into waters off the coast of Canada—projects that are beyond present facilities. None the less, some work on this phase was accomplished during 1935 by a less expensive (and also less promising) method involving studies of meristic characters to distinguish different races or types within the population. Since the subdivisions of the population may be expected to occur mixed at one time and separate at another, and to change in locality with increase in age, the subject is more complex than the usual racial study and hence less likely to yield to this method of investigation.

SHORE FISHES OF THE MIDDLE ATLANTIC STATES

The ultimate object of these investigations, under the direction of R. A. Nesbit, is to provide a rational basis for more efficient utilization of the fishery resources of the waters between Cape Cod and Cape Hatteras. Two requirements must be met if this objective is to be attained: (1) The life histories and conservation needs of all

[3] See Outlook for the Mackerel Fishery in 1933 by O. E. Sette; Bureau of Fisheries, Fishery Circular No. 14, pp. 11–12. May 1933.

important species must be known; and (2) some provision must eventually be made for unified administration.

Thus far, limited appropriations have permitted inclusion of only a few of the several important species in the investigational program, and it has not been possible to maintain continuous and simultaneous observation of even these few over the whole region. This is unfortunate for it has become increasingly apparent that all important species and all localities must be considered together in drafting conservation recommendations. The more productive forms of fishing gear, pound nets, otter trawls, and purse seines, take more than one species, so that protection of one species may interfere with legitimate exploitation of other species. In order to complete the program and to render effective the results of past efforts, it will be necessary to provide for extension of activities to include investigaton of sea bass, croakers, summer flounders, winter flounders, bluefish, shad, and striped bass.

The need for unified or coordinated administration arises from the migratory habits of the fish, and from the interstate traffic in the products of the fishery.

Squeteague.—The more important features of squeteague life history and certain conservation considerations based on them have been presented in earlier reports of this series. For convenience these are summarized as follows:

(1) Squeteague spawn in inshore waters from Massachusetts to North Carolina in late spring and early summer, but there is considerable doubt as to whether there is significant survival from spawning north of the coast of Virginia.

(2) Nearly all squeteague spend their yearling summer south of Delaware Bay, so that that portion of the range constitutes a nursery area in which yearling squeteague predominate in the catches, while the area north of Delaware Bay is frequented by 2-year-old fish or older—the survivors of the southern fishery for yearlings.

(3) Squeteague grow much more rapidly north of Delaware Bay than in southern waters.

(4) The decline in numbers of large squeteague in the Middle Atlantic States, especially in northern New Jersey and New York, has not been caused by excessive fishing locally but by increased fishing for yearlings in the southern nursery areas.

(5) The southern fishing for yearlings involves the capture and destruction of some squeteague too small to be marketed. In the report for 1934 it was recommended that experiments be undertaken to determine whether the waste of undersized squeteague could be mitigated or eliminated by changes in the design of pound nets.

In 1935, R. A. Nesbit actively engaged in, or directed (1) a preliminary survey by W. C. Neville of pound net fishing methods in Virginia and North Carolina to observe further the extent of waste of small fish and to secure a basis for planning the experiments referred to above when resources become available; (2) further examination of scale and length-frequency data, including samples taken by Mr. Neville in the southern survey. The results of these activities are discussed separately below.

In Pamlico Sound, N. C., Mr. Neville found conditions in early July very similar to those reported by Higgins and Pearson [4] for 1925. Eight random samples totaling 1,164 squeteague were taken at the nets. Of these, 308, or 26.5 percent, were below legal size. Since squeteague of barely legal size are not desirable, some squeteague slightly longer than 9 inches were discarded so that approximately 30 percent of the catch was not utilized at the time and in the locality covered by observations. In Chesapeake Bay 16 random samples totaling 1,610 squeteague were taken in later June. Of these, 118, or 7.3 percent, were below the legal minimum. From traps set in the ocean near Hog Island and off Virginia Beach, Va., 14 random samples totaling 1,806 squeteague were secured. Of these, only 45, or 2.5 percent, were undersized.

In 1929, when extensive series of samples were secured from the traps in Chesapeake Bay and from those near Hog Island, the waste of undersized fish was negligible. In that year it was also noted that yearling squeteague did not appear in the Virginia catches until August, when most of them were above the legal minimum. It is probable, therefore, that waste of undersized squeteague seldom, if ever, reaches very large proportions in Virginia.

In the Pamlico Sound region of North Carolina, however, waste of small fish, especially in the early summer months, appears to be of considerable magnitude. Of especial interest, therefore, is the observation (based on examination of the circulus spacing on the scales) that more than half of the 1935 yearlings consisted of squeteague which had spent the latter part of the preceding summer north of Delaware Bay. If these fish had survived, most of them would have returned to the North in 1936. It is apparent, therefore, that the conditions described by Higgins and Pearson in 1925 and the recommendations made by them are of more than local significance.

Further examination of northern scale collections indicates that there are two groups of squeteague in the Middle Atlantic region. The first of these appears as 2-year-old fish in southern New Jersey after having spent their yearling summer in the South. Although some of these fish continue to return to southern New Jersey in succeeding years, most of the survivors of the southern New Jersey fishery spend their summers in northern New Jersey and western Long Island, N. Y., when 3 years old or older. Since the fishery in southern New Jersey has increased during the last 15 years, the increased mortality among 2-year-old squeteague of this group has undoubtedly contributed to the diminution in numbers of large squeteague in northern New Jersey and western Long Island. Restriction of the fishing in southern New Jersey would probably be of little benefit, however, for the 2-year-old fish produced there compete in the markets with the Virginia and North Carolina yearlings. Elimination of these fish from the market would stimulate the southern fishery toward a still heavier toll of yearlings, perhaps resulting in a still further decrease in abundance in northern New Jersey.

[4] Higgins, Elmer, and J. C. Pearson. Examination of the summer fisheries of Pamlico and Core Sounds, N. C., with special reference to the destruction of undersized fish and the protection of the gray trout, *Cynoscion regalis* (Bloch & Schneider). Bureau of Fisheries, Document 1019, 1927.

The second group appears as 2-year-old fish in eastern Long Island, N. Y., after having spent their yearling summer in the South. Many of these fish continue to return to this locality in succeeding years, but it is possible that the large squeteague occurring in southern New England belong to this group. This eastern Long Island group differs from the New Jersey-western Long Island group in that it provides larger catches in the spring and early summer than in autumn, while in New Jersey the reverse is the case. This suggests an explanation of the invasion of New York and southern New England [5] by remarkable numbers of large squeteague 30 years ago. All accounts agree that these large fish were not preceded by exceptional numbers of small fish, and in eastern Long Island, at least, it is known that they were present only in late summer and autumn, the spring catches having been actually smaller than those of the years preceding and following the run of large fish. Hence, it appears that this phenomenon was the result of a temporary extension of the range of the New Jersey-western Long Island group.

From the foregoing it is apparent that the problem of squeteague conservation presents quite different aspects according to the point of view from which it is examined. From the point of view of the commercial fishermen and anglers of New York and New Jersey, all fishing for squeteague south of Delaware Bay is disadvantageous. From the point of view of southern fishermen, it is probable that little or nothing is to be gained by protection of yearlings after they have reached marketable size. For growth is so slow in southern waters that it is very doubtful whether the growth of those yearlings which remain in the South compensates for the losses from natural mortality and from emigration to northern feeding grounds. If the problem be considered from a national rather than from a sectional point of view, it must be admitted that insufficient data are available to permit a decision as to whether sufficient benefit would result from curtailment of the southern catch of yearlings to compensate for the resulting losses.

The more important items of gain and loss can be listed but their magnitude cannot be estimated closely at present. The principal gain would be an increase in abundance of squeteague in New Jersey and New York. Since these would be medium and large squeteague which bring better prices than small sizes, the gain in value would be even greater than the gain in pounds. Increased abundance of the larger sizes which frequent the waters of northern New Jersey and New York would improve angling conditions and the important business of catering to anglers would be stimulated. Against these gains must be set not only the loss to the southern fishery of the squeteague protected there, but the losses due to curtailment of the catch of other species as well, for most squeteague are taken in pound nets which also take considerable quantities of other species not all of which appear to need protection.

Even if it could be shown beyond doubt that the greatest good to the greatest number could be accomplished by curtailment of south-

[5] Bigelow, H. B. and W. W. Welsh. Fishes of the Gulf of Maine. Bulletin, U. S. Bureau of Fisheries, vol. 40, pt. 1, 1924 (1925).

ern fishing, there exists no practical means of accomplishing such a curtailment, for control of the fisheries in territorial waters is vested in the several States. Experience has shown that local interests are considered first when conservation measures are proposed. It is not to be expected, therefore, that the individual States will adopt conservation measures other than those likely to benefit the local fisheries.

However, all sections can endorse the proposal to seek a practical means of preventing the destruction of squeteague too small to be marketed; but until funds are made available, the necessary observations and experiments cannot be undertaken.

Scup.—Investigation of this species was continued by W. C. Neville. Catch records of the summer fishery in 1934 were compiled and analyzed, observation of the winter trawl fishery was continued, and progress was made on a comprehensive report dealing with the life history and the conservation requirements of scup.

Attention has been focused on observation of the effects of the increased exploitation to which scup has been subjected in recent years. Most of this increase is due to the winter fishery, the scup catch of which has more than doubled since 1931 (rising from approximately 1,686,000 pounds in that year to 3,844,000 pounds in 1935). To a large extent the increases are due to the greater numbers of vessels engaged in the fishery. It is difficult to measure changes in abundance closely, for the catch of each of four species, scup, sea bass, fluke, and croakers, is influenced greatly by variations in availability due to changes in hydrographic conditions, and by varying market preferences. Everything considered, however, it appears that abundance has remained high or even increased somewhat in spite of the increased fishery.

Nor has there been, thus far, indication of diminution in the average annual increments to the stock. Continued high yields from the New Jersey summer pound-net fishery, in which the younger-age groups predominate, indicate that most recent spawnings have been very productive. In the winter fishery also, the younger age groups have been well represented. Of the year classes since that of 1926, only the 1929 and the 1933 year classes have been below average.

There is no need to reduce the catch of scup in order to increase the numbers of spawning adults. The annual increments of young are extremely variable, and to a very great extent are independent of the numbers of spawners. For example, the abundant 1927 and 1928 year classes were produced in years in which the numbers of spawners were relatively small, but in 1933, when spawners were very abundant, spawning was comparatively unproductive. The results of tagging experiments also suggest that the present catch of adult scup does not cause excessive reduction of scup of spawning age. In no case has the percentage of tags returned exceeded 3 percent. Since returns from squeteague, flounder, cod, and striped bass experiments range from 10 to 30 percent, it appears that the scup fishery imposes a much smaller strain on the spawning stock.

Although the present catch of marketable sizes of scup is not excessive, present methods of fishing cause considerable waste of scup too small to be marketed. This necessarily reduces the abundance

of marketable scup in subsequent years, thereby increasing the costs of catching them. Because of lack of funds, it has not been possible to devise practical savings gear to permit the escape of the unmarketable sizes.

FISHERY INVESTIGATIONS OF THE SOUTH ATLANTIC AND GULF COASTS

SHRIMP

MILTON J. LINDNER, *in charge*

As in preceding years, excellent cooperation in the investigation of the natural history and abundance of the shrimp has been furnished by the Louisiana Department of Conservation, the Texas Game, Fish and Oyster Commission, and the Georgia Tidewater Department. Offices and laboratory facilities have been supplied by the Louisiana Department of Conservation, the Georgia Tidewater Department, and the San Patricio Canning Co. Headquarters have been maintained in New Orleans and field stations were located at Beaufort, N. C.; Brunswick, Ga.; and Aransas Pass, Tex. During the spring of 1935 John C. Pearson was transferred from New Orleans, La., to St. Augustine, Fla., to continue his studies on the eggs and larvae of the shrimp.

The common shrimp, *Penaeus setiferus*, because of its outstanding dominance of the fishery, has received most of the attention of the investigators. At least 95 percent of the shrimp catch is composed of individuals of this species.

Shrimp still ranks preeminent among the sea foods of the South, and the shrimp fishery with an annual catch of approximately 100,000,000 pounds is one of the major fisheries of this country. Results of studies in 1935 have shown that this fishery undergoes sharp fluctuations. Shrimp were exceedingly scarce in the spring and early summer of 1935. In spite of this scarcity, which was general throughout the entire South Atlantic and Gulf, the late summer and fall fishery proved to be relatively successful in most localities. The Georgia and Florida fall fisheries in particular were much improved as compared with the previous several years. On the other hand, in some localities, particularly Corpus Christi Bay, Tex., the fall catch has been much less than expected. These fluctuations indicate that definite changes in the magnitude of the shrimp population do occur, and that for a complete understanding of the fishery a study of these changes must be made, their nature and causes determined, and the effect the fishery has upon them ascertained.

Such studies are complicated by the fact that the shrimp fishery is not established at a constant level, but is marked by a continual expansion and increase in fishing effort, which has been particularly evident along the South Atlantic coast. More and larger boats drawing larger nets, introduction of Diesel power, and the conversion of gasoline engines to the use of cheaper fuel have all contributed toward this increase. Consequently it is of vital importance that the proper type of statistical system be introduced as soon as possible in order that the trend of the abundance of the fishery be followed, the fluctuations of supply determined, and an understanding of their causes secured. Due to the constantly increasing effort it is impossible, with

the present inadequate records, to secure an estimation of the fluctuations. Since the shrimp fishery extends over practically the entire coastal area of eight Southern States, it is impossible for the present staff to gather these statistics in the detail in which they should be secured.

Sexual maturity.—At Beaufort, N. C., Dr. J. S. Gutsell completed his studies of the structure and development of ovaries and ovarian eggs of the commercial species of shrimp and is finishing a report on his findings. This investigation has shown that in the Beaufort region the common shrimps in many instances probably spawn at least twice during the spawning season. Spawning at Beaufort is most active in May, but continues throughout the summer and a large part of the autumn. It seems probable that some of the shrimp in this vicinity may survive through two winters and spawn during the second year. In any event, the numbers which spawn in their second year appear to be exceedingly few. Definite criteria have been found for mature and spent ovaries.

Food.—Since the completion of the ovarian studies Dr. Gutsell has been engaged in determining the food of the shrimp and has examined the contents of hundreds of stomachs of the common shrimp, *P. setiferus*, and the grooved shrimp, *P. brasiliensis*, including a considerable number from young of 1 to 3 inches in length. In addition, shrimp have been kept in aquaria and fed various foods. Fish, shrimp, and oysters were readily eaten, but an apparent preference seemed to be shown for small barnacles. The stomach contents indicate that the principal natural diet appears to be small crustacea (such as Cumacea) and polychaete worms. Both these forms are generally found burrowing in mud or sand, where they are apparently readily found by the shrimp. Mollusks, barnacles, fish, plants, and plant material, including diatoms, small filamentous algae, pieces of tissue from higher plants, and sand are also found in the stomachs of the shrimp.

Since the variation in food supply may vitally affect the abundance and distribution of shrimp, it is a subject which cannot be neglected in the present study, and which may give an important clew to the causes of fluctuation in the shrimp fishery.

Weight-length.—In Texas, Kenneth H. Mosher has continued the sampling of the commercial catches during 1935. A total of 9,773 shrimp were measured and examined for stage of sexual maturity. Of this number, 5,435 were from Aransas Pass, 4,038 were from Galveston, and 300 were from Port O'Connor. The relative importance of *P. setiferus* is indicated by the fact that of all the shrimp examined throughout the entire year over 98 percent were of this species. In addition to the length measurements, Mr. Mosher weighed 4,200 shrimp in order to obtain an extensive list of data from which to compute the weight-length relationship. These data show that seasonal differences occur in the weight-length relationship, and may, therefore, throw light on various questions concerning shrimp biology; for example, on whether or not overcrowding of the population exists. This study will therefore be continued.

Larvae.—Our understanding of the life histories of the two commercial shrimp, *P. setiferus* and *P. brasiliensis* and other peneids has become more clarified during the past year by the recognition of the early growth stages of both species by John C. Pearson who has been

stationed at St. Augustine, Fla. From living and preserved material these species of shrimp have been traced through the egg, nauplius, zoea, and mysis stages of development. It was essential that the eggs and young be distinguished before any clear-cut conception of their early life histories could be possible. It is interesting that the peneids undergo more molts and stages of growth than any other group of decapod crustaceans. Nevertheless probably no complete series of larval forms has yet been traced out for any single species of the *Penæidae*. The present studies on eggs and young of these commercially important shrimps not only establish the distinctive morphological features during larval life, but also contribute significantly to our knowledge of the spawning season and the distribution of the young.

Observations at St. Augustine and Fort Pierce, Fla., have proved definitely that many eggs and planktonic young of these two species of commercial shrimp come into the shallow estuarian rivers and lagoons from the ocean through the various inlets. The spawning season along the Georgia and Florida coasts, as previously indicated by examination of ripe adults, extends at least from March into September for the common shrimp, and probably throughout the year for the grooved shrimp, which appears to be a more characteristically offshore and deeper water species.

During the coming year intensive study will be made on the living eggs and young of these southern shrimps to ascertain among other things the rate of development at various stages, the rapidity of the natural movement of young, and the possible factors influencing mortality.

Migrations.—Regular sampling of the shrimp population along the South Atlantic coast aboard Fisheries Launch *58* was continued by W. W. Anderson for the first 6 months of 1935. The territory covered extended from Cape Romain, S. C., to Cape Canaveral, Fla. As in previous years, nine outside and two inside stations were visited regularly once each month. The particular area covered represents by far the greater portion of the shrimp-fishing localities on the South Atlantic coast. The stations were so established as to be from 35 to 50 miles apart and to cover the more important fishing centers along the coast, in this way giving us a fairly representative sample of the entire fishery. At each station at least two hauls of ½-hour duration each were made with a 50-foot otter trawl. Plankton tows were made and water temperatures and salinities recorded for every station. Shrimps from each haul were measured and the stages of gonad development observed. All fishes taken in the hauls were recorded as to species and numbers. During the last 6 months of the year such sampling was discontinued in stations north of Brunswick, Ga., but maintained from Brunswick, Ga., to Cape Canaveral, Fla.

As mentioned in the previous annual report, the data gathered aboard Launch *58* indicated quite definitely that a migration of shrimp occurs along the South Atlantic coast. During the fall and winter of each year it was observed that large shrimp disappear from the Georgia coast. At the same time an important fishery for such large shrimp developed off the central Florida coast from St. Augustine to Cape Canaveral. These two facts suggested four pos-

sible explanations; namely: (1) A southern migration into Florida of the larger Georgia shrimp during the fall and winter. (2) Depletion through fishing of the large Georgia shrimp, while the Florida fishery was maintained by natural growth of native shrimp. (3) A winter offshore movement in Georgia of the more developed shrimp. (4) A combination of any two or all three of the above possibilities. The regular and recurrent nature of these phenomena leads us to believe that migration is probably the most important factor influencing them.

Measurements were made by Mr. Lindner in an attempt to determine whether or not differences in body proportion existed which would make possible the identification of shrimp as to point of origin. It was found that although racial differences do seem to occur in the shrimp, possible intermingling and probable seasonal and environmental changes in body proportion have made it impossible to interpret these data without experimental studies.

Tagging experiments were conducted on confined shrimp at Aransas Pass, Tex., by Mr. Mosher and Mr. Lindner in order to determine the feasibility and best means of marking. These experiments showed that the celluloid disc type of tag affixed to the first abdominal somite of the shrimp was most probably the best method as it apparently interfered less with movements and molting, and was retained better than other devices. During September, October, and November this method was placed in practice in the field by Mr. Lindner and Mr. Anderson. A total of 3,800 shrimp were tagged along the Georgia and Florida coasts.

The success of this method of tagging is evidenced by the fact that by the end of December almost one-fourth of the tagged shrimp had been taken by the fishermen and returned to the investigators. Although these experiments are by no means completed it is quite evident that there does occur a southward movement of shrimp from Georgia into Florida during the fall and winter. Some of the tagged shrimp had moved distances upwards of 200 miles. The success of the Florida winter fishery probably thus depends to a large extent upon the production of shrimp in Georgia, and upon these shrimp escaping the Georgia fishermen. The numerous returns indicate that the fishery is very intense. The importance of continuing these studies is obvious.

During the coming year tagging operations will be extended throughout the entire area of the South Atlantic shrimp fishery in order to determine whether there is a return movement of shrimp from Florida to Georgia in the spring, and also to discover the direction and extent of the migrations along the North and South Carolina coasts. Data have been collected which indicate that there may also be a winter concentration of shrimp in the vicinity of Cape Hatteras. In addition, arrangements have been made for securing a pond in the vicinity of Brunswick, Ga., where experiments can be conducted to determine the mortality owing to tagging. From these experiments, and from the tagging returns it is hoped that some conclusions can be derived as to the actual intensity of the fishery.

It is evident from data gathered in Louisiana and Texas that the Gulf shrimp also are migratory. Throughout the fall and winter it is customary for the majority of large shrimp to disappear from

the usual coastal fishing grounds. Evidence has been secured which leads to the belief that during the winter the shrimp move offshore to the deeper and warmer waters of the Gulf. With suitable vessel equipment, which this investigation does not now possess, it should be possible, through extensive fishing during the fall and winter in the offshore waters, to determine whether or not this is the case and also whether or not the shrimp congregate in sufficient quantities in these areas to make a commercial fishery feasible at this time.

In Texas during the coming year, if arrangements can be made, intensive tagging experiments will be conducted over the entire fishing area. It is hoped through marking experiments to be able to determine the intensity of fishing, particularly in Corpus Christi Bay. It is also probable that at the same time valuable data will be secured on the coastal or offshore movement of the Texas shrimp.

GREAT LAKES FISHERY INVESTIGATION

JOHN VAN OOSTEN, *in charge*

As in 1934, virtually no field work was conducted on the Great Lakes during the calendar year 1935. F. W. Jobes spent 1 week in February at Put in Bay, Ohio, obtaining a collection of young perch from the Ohio Division of Conservation, and Dr. Van Oosten spent 1 week in July at Port Huron, Mich., observing the whitefish catch in deep trap nets with special reference to the percentage of undersized fish taken in waters less than 80 feet deep.

The Bureau maintained its cordial relations with the various Great Lakes States, and provided considerable assistance in drafting and revising fisheries legislation and submitting pertinent data. Ohio submitted 5 bills affecting commercial fisheries; Michigan, 13; and Wisconsin, 12, one of which involved the complete recodification of its laws governing the Great Lakes fisheries.

Dr. Van Oosten represented the Bureau at 10 conferences and meetings during the year, and at some of these presented papers.

FISHERY STATISTICS

A major project undertaken without benefit of precedent was the initiation by the Bureau of Fisheries in 1933 of a detailed statistical study of the Great Lakes fisheries in waters under the jurisdiction of the State of Michigan, based on reports of daily fishing activity submitted at the end of each month by all licensed fishermen represented. The Great Lakes fisheries present so many peculiarities that the statistical methods employed in the study of other fisheries are, in general, not applicable. The consequent necessity for the development of special methods adapted specifically to the investigation of Great Lakes fisheries made it imperative that the first analyses and tabulations of statistical data be carried out in the minutest detail. The task was made the more onerous by reason of the fact that the compilation of the statistics of 3 earlier years (1929–32) had to be made in addition to that of the statistics of the current year. The basic tabulations of statistical data have now been completed for all Great Lakes waters under the jurisdiction of the State of Michigan

for the 6-year period, 1929–34. In addition, detailed statistical summaries for the different calendar years have been prepared for the Michigan waters of Lake Huron, Lake Erie, and Lake Michigan for the same period.

Progress in the statistical study of the Great Lakes commercial fisheries during 1935 has by no means been limited to bringing tabulations of original data up to date. The modification of methods of procedure, and the detection of sources of error have added much to the reliability of the statistical results. As an illustration, it may be mentioned that the original geographical boundaries of some of the statistical districts proved unsatisfactory and had to be revised. A more unusual difficulty was that presented by the discovery of numerous misstatements relative to the type of gear employed. A serious distortion of the statistics of the fishery (particularly the whitefish fishery) was avoided only by means of a detailed study, requiring several months, of the fishing activities from month to month of individual fishermen and individual vessels. Conclusions drawn from these studies were carefully substantiated from other sources.

Attention has been directed also toward the critical examination of the basic assumption and definitions upon which the original methods of procedure were founded. In this connection the observations on the relationship between fishing time of stationary gear and size of lift are particularly striking. Doubling the amount of time that gear is fished before it is lifted does not double the catch, but on the average increases it only 10 to 20 percent. This relationship together with the fact that the average fishing time for a given type of gear fluctuates within narrow limits from year to year in a single fishing area may make it possible to dispense entirely with fishing time in the treatment of statistical data. Certainly the earlier definition of the "catch per net per night" as the most discriminating measure of abundance will require modification.

In order that annual fluctuations in the abundance of each species in a given area may be expressed more concisely, effort is being directed toward the development of a method of expressing these fluctuations in terms of index numbers. The index number is derived through the comparison of the actual catch of a given species for a given year and in a certain locality with the "expected" catch as computed from the known intensity of the fishery.

PIKE PERCHES

A manuscript dealing with various phases of the economics, life histories, and racial affinities of the pike perches (Stizostedion) of Lake Erie has been partially completed by H. J. Deason. Many conclusions resulting from this investigation have been presented previously in Progress in Biological Inquiries for the years 1933 and 1934. Additional conclusions have been reached in 1935.

The male and female saugers grow at approximately the same rate for the first 3 years of life while in the yellow pike perch, the same relative growth rate extends through the first 4 years of life, following which the females of both species grow more rapidly than the males.

A mathematical expression of the length-weight relationship in terms of the formula $y = ax^n$ has been obtained for each of the three species; namely, sauger, yellow pike perch, and blue pike perch. The weight of each species tends to increase approximately as the 3.15 power of the length. (A slightly different value was obtained for each of the three species.) The "relative heaviness" or "state of well-being" of the pike perches, as expressed by a coefficient of conditions, K, obtained by the formula

$$K = \frac{W.10^{-5}}{L^3}$$

has been found to vary with the length of the individual, with sex, and according to the season of the year. No variation with respect to locality was found.

A history of the pike-perch fishery of Lake Erie has been completed. Sources include publications of various United States and Canadian agencies as well as valuable unpublished records obtained from certain commercial fishermen of Lake Erie.

YELLOW PERCH

Virtually all of the available data collected during the years 1927–32 on the age and growth of the yellow perch have been drawn up in summary tables. The growth data (lengths and increments), based largely on the measurements of scales, have been analyzed with respect to age groups, year classes, sex, and localities. Age composition of the commercial catch has been ascertained with respect to both seasonal fluctuations and locality. Individual weights of approximately 18,000 yellow perch have been tabulated by 5 millimeter frequency intervals and have been subjected to analysis with respect to type of gear, size of mesh, seasons, sex, sexual maturity, and locality. Length frequencies were compiled to show variations with respect to gear, seasons, and locality. The work on the yellow perch was discontinued in June when F. W. Jobes was transferred to the Washington office.

CURRENT PROJECTS

Current projects involve largely the writing of reports covering the major investigations completed in the field. Such projects include the 5-year investigation on Lake Erie; the 2-year survey of deep trap net operations on Lakes Huron and Michigan; the three seasons' work on the chub nets of Lake Michigan, including studies on temperature and currents; and life histories of the whitefish of Lakes Huron and Erie, the cisco of Lake Erie, the sheepshead of Lake Erie, the chub of Lake Superior, and the herring of Lake Huron.

PACIFIC COAST AND ALASKA FISHERY INVESTIGATIONS

FREDERICK A. DAVIDSON, *in charge*

The Pacific coast and Alaska fishery investigations were confined mainly to studies of the salmon fisheries in the Pacific Northwest States and the salmon and herring fisheries of Alaska. The major investigations of the salmon and herring fisheries conducted in these

regions in 1934 were continued during 1935. In addition, a new and much-needed investigation dealing with the collection and statistical analysis of daily catch records of the various types of fishing gear used in the salmon fisheries of Alaska was carried on in 1935.

COLUMBIA RIVER

The investigation of the fisheries of the Columbia River was conducted during 1935 by J. A. Craig, assisted by A. J. Suomela. The activities of this investigation can be summarized under several divisions, each forming a part of the general program for the acquisition of facts essential to the preservation of these important fisheries.

One of the phases which is of fundamental importance is the study of the annual and seasonal fluctuations in the abundance of the important species of fish contributing to the Columbia River fisheries. These fluctuations are being ascertained from a statistical study of the catch records of individual pieces of gear employed in the commercial fishery. Records have been made available through the cooperation of the commercial fishing interests on the river, and some of them extend back as far as 1897. All of the original records of the catches of all important commercial species, namely, chinook, blueback, chum and silver salmon, steelhead trout, and sturgeon, made with gill nets, traps, and seines, have been copied from 1897 to 1934, inclusive. Since the chinook salmon are by far the most numerous and important species frequenting this river system, indexes of their abundance are being computed first. Practically all of the gross tabulations and summaries of these data have been completed within the year.

Another major division of this investigation is the stream survey program. The object of these surveys is to obtain data which will be a guide to the improvement and rehabilitation of the spawning areas in the Columbia River system.

In the course of this work field parties secured information on (1) the total area in each tributary which forms the present and past spawning areas for migratory species of fish; (2) the location of the spawning areas now available to salmon; (3) the location of the areas which have been made unavailable to salmon, and the cause of their destruction; (4) the sources of pollution which may be detrimental to spawning populations of salmon and to resident fingerlings; (5) the number and location of irrigation canals and their effect on migratory fishes; (6) the location of natural and artificial obstructions, and the extent to which these form barriers to upstream migrants; (7) the general status of the salmon populations in the Columbia River.

During the present year, 1935, the survey has progressed satisfactorily, especially so from the advent of summer to the close of the year. The activities have been concentrated principally in eastern Washington on tributary streams below Grand Coulee. The streams on which surveys have been completed are: Methow, Entiat, and the Wenatchee. The Okanogan has been partially surveyed. In the Yakima system the tributaries examined to date are as follows: Naches River with its tributaries, namely, American River, Bumping River, Rattlesnake Creek, and Tieton River; and Ahtanum Creek, Satus Creek, Kachess and Cle Elum Rivers, which empty

directly into the Yakima River. In the southeastern section of the State of Washington partial surveys of the Walla Walla River, Mill Creek, and Asotin Creek have been made, and the examination of the Touchet and Tucannon Rivers is finished. Surveys of Alochoman and Wind Rivers in the lower Columbia are under way, while the Washougal River survey was completed. A total of 1,100 miles of tributary streams was surveyed during the year.

Because of the fact that all of the salmon and steelhead trout which reach Grand Coulee Dam after its completion must be artificially spawned and their offspring cared for in a hatchery, it became necessary to know the numbers and species of these fish migrating past the dam site so that proper hatchery facilities could be provided for them. In connection with this problem, counting weirs were installed in both fish ladders of the Rock Island Dam of the Puget Sound Power & Light Co. Observers were stationed there to count the fish during the entire year. The total numbers of salmon and steelhead trout passing over this dam in 1935 were: Chinook salmon, 16,310; blueback salmon, 14,013; silver salmon, 11; and steelhead trout, 5,412. This counting was done in cooperation with the Washington State Fisheries Department.

A counting weir was maintained in the fish ladder of the Tumwater Dam on the Wenatchee River during the late summer and early fall when the blueback salmon were ascending that tributary. During that time 889 blueback salmon, 4 chinooks and 7 steelheads ascended the ladder. Another counting weir was operated at Oroville, Wash., where 10 chinooks and 264 blueback salmon were counted. From surveys made of spawning grounds, records of the Indians' catches at Kettle Falls, and other sources of evidence, it appears that the majority of the fish counted over the Rock Island Dam go on past the Grand Coulee dam site and seek spawning grounds largely in British Columbia. Fortunately, a great deal of work on the life history and habits of the salmon of the Columbia has been done (by Rich, Holmes, and others) thus making that phase of the investigation seemingly less pressing than some of the others. However, every opportunity was taken advantage of to secure material for such work. Large collections of the migrants, both salmon and steelheads, were made in the Yakima River, and scales were taken from steelheads and salmon at the Rock Island and Tumwater weirs.

The investigation of the mechanism of the homing instincts of the blueback or sockeye salmon, initiated before Mr. Craig was transferred to the Columbia River work, was continued. Ten thousand sockeye migrants in their second year were marked and liberated in Diobsud Creek, a tributary of the Skagit River, as a check on the extensive marking experiments of 1934 in that system. The first returns from these experiments are expected in the fall of 1936.

In order to have a complete understanding of the fishery problems of the Columbia River system, it has been necessary to do a considerable amount of research on the history and development of these fisheries, and on the development and utilization of other natural resources such as water power, agricultural land, and forests which have influenced the fish populations by bringing about changes in

their habitats. A report on this part of the investigation is now in the process of preparation.

As a result of cooperative work between the United States Bureau of Fisheries and the Washington State Fisheries Department, evidence was collected and presented which indicated the necessity for a third fish ladder at the middle of the Rock Island Dam on the main Columbia River. This ladder is now being constructed and will be in use during the summer of 1936.

PUGET SOUND SOCKEYE SALMON

Since the publication in March 1935, of the preliminary report on the salmon fisheries of the Puget Sound-Frasier River region by Dr. George A. Rounsefell and George B. Kelez, entitled Abundance and Seasonal Occurrence of the Salmon in the Puget Sound Region and the Development of the Fishery,[6] the sockeye investigation has been concerned largely with obtaining sufficient data to clarify many of the points only hinted at in the preliminary study. The collection of statistics on the catches of fish traps and seines in Puget Sound was continued in cooperation with the coho investigation. Special efforts were made to obtain sufficient purse seine data covering the fall months, and considerable success was achieved.

The records of daily catches were obtained for over 76 percent of the salmon traps operated during the past 20 years, and a considerable percentage of all of the traps operated since 1895. These data are being tabulated so as to show the seasonal occurrence of all species of salmon in each of the main fishing areas. Furthermore, the total annual catches made by each of the traps since 1915 have been ascertained, thereby making available the quantities of salmon taken in each area.

The sockeye investigation has obtained records of individual daily catches by gill nets on the Fraser River of all species of salmon throughout each season from 1898 to 1935. Preliminary analysis of these data has shown distinct differences in the efficiency of Japanese, white, and Indian fishermen. Records have been obtained of all the licenses from 1900 to 1935, and these are being studied to discover the variations in numbers of each of these three classes of fishermen.

The Division of Fish Culture has cooperated with the sockeye investigation by planting 76,000 fingerling sockeyes from the Birdsview hatchery in Cedar River, a tributary of Lake Washington; and another 76,000 in Issaquah Creek, a tributary of Lake Sammamish, which empties into Lake Washington through the Sammamish River. These two lakes appear to be the most suitable in the Puget Sound region of the State of Washington for the establishment of sockeye salmon. At present they both support runs of coho salmon.

During the 1935 season biological data were collected from the commercial catches of sockeye, pink, and chum salmon from various areas within Puget Sound as well as from Swiftsure Bank. From July 22 to November 20, scales and length measurements were taken on 55 samples of sockeyes comprising 2,529 fish. Weights were taken

[6] Special Report, Washington, 1935 (multigraphed).

on 2,229 of these. The same data were obtained on 1,430 chum salmon in 36 samples. Length and weight data were taken on 830 pink salmon in 17 samples.

Considerable attention has been given to tracing the early history of the fishery so as to be able to utilize past experience on the effect of the fishery on each species in deciding what effects to expect in the future.

WASHINGTON COHO SALMON

The coho salmon investigation on Puget Sound, the purpose of which is to determine the life history of the species, changes in its abundance together with their underlying causes, and methods of rehabilitating population in streams now barren or depleted, was continued during the past year under the direction of George B. Kelez.

A continuous series of fingerling collections was made in McMillin Creek to determine the rate of growth of the fish from the time of hatching until the time of seaward migration. Because of differences of temperature as great as 10° C. between various streams of the region at the same time in the summer, a series of samples was taken from all major streams and tributaries during the last week in June. A preliminary analysis of this material shows a size range from 34 to 59 mm with a mean of 40 mm in the colder streams, and a range from 48 to 71 mm with a mean of 60 mm in the warmer ones.

Two marking experiments were undertaken this season on Voight Creek, a tributary to the Puyallup River, in the southern part of the region. The fingerlings used were provided through the cooperation of the Washington State Department of Fisheries. In the first experiment, 50,000 fingerlings reared from eggs taken in November and hatched during February 1934 were marked by the removal of the dorsal and right ventral fins. The fish marked each day were held 24 hours to determine any loss due to handling and were liberated in the stream. This marking was carried on during the period from May 13 to May 19, 1935. For the second experiment, 25,000 fingerlings of the same age hatched and reared at the State hatchery on the Green River were moved to Voight Creek and marked by the removal of the adipose and both dorsal fins. The lots of fish marked each day were held for 24 hours in the stream and then liberated. This experiment was carried on between May 28 and June 3, 1935.

The first experiment is expected to furnish information on certain phases of the life history of the coho salmon such as the "homing instinct", migration routes, and time of appearance of this particular run, through recoveries of adult fish both from the commercial fisheries and from the stream itself during the spawning run. The second experiment is intended to determine the success of transplanting coho salmon of the fingerling size in a stream entirely separate from that of their nativity. Adult fish resulting from the fingerlings transplanted to Voight Creek must pass the mouth of the more northerly Green River, their native stream, before reaching the mouth of the Puyallup. If the tendency is to return to the Green River they will be taken at the hatchery rack there; the proportion returning to the Puyallup will indicate the success of transplanting fish of this size.

The first recoveries from a similar set of experiments carried on in 1934 at the Samish River, in the northern region of the Sound, were made during the spawning migration of the present season. Six of these fish, returning as grilse from the marking of November 1934, were recovered with a dip net at the Samish rack. One was reported as taken by a sport fisherman below the rack, and several others escaped, being small enough to pass through the rack. No returning grilse were observed from the earlier Samanish experiments, those of May 1934.

Collections of biological data from both commercial and sport fisheries were made throughout the season. Scale samples and data as to length and sex were taken for over 3,000 fish obtained from the commercial fishery between July 22 and November 20, when the fishing season closed. Weights taken from 2,700 of these fish indicated an exceptional growth during the third year of their lives. Scale samples and measurements were also obtained from several hundred fish in their second year taken by sport fishermen.

The collection of data was continued on individual catches by all types of gear on Puget Sound since the beginning of the fishing industry there. Almost all the material of this nature still in existence has now been obtained from the records of the industry. This is being analyzed to determine changes in abundance, time of runs and the importance of the various fishing areas.

KARLUK RIVER RED SALMON

An investigation of the red salmon runs of the Karluk River, Alaska, was continued by J. T. Barnaby, assisted by L. D. Townsend and J. F. Hart.

Another marking experiment was initiated, 49,092 seaward migrants being marked by the amputation of the left ventral and adipose fins. The returns from various marking experiments have ranged from 20 to 25 percent of the migrants marked. Thus the ocean mortality from seaward migrant stage to adult stage is apparently about 75 percent. If we assume the return of only two adults for each spawner, the assumption upon which the existing statute limiting the commercial catch to 50 percent of the total run is based, and if we assume that each female produces the known average of 3,500 eggs, the mortality during the fresh water period, or from eggs to seaward migrants may be calculated under these conditions to be 99.54 percent.

Since the greatest mortality of this species takes place during the fresh-water period of its life history, further studies were made on the environmental factors which influence the success of each year's spawning. Physical and chemical data were collected throughout the summer. The chemical analysis of the lake and stream waters indicates that phosphorus and silicon are limiting factors in the production of plankton, at least during the major part of the summer. The water of the streams entering the lake contained on the average 2 one-hundredths of a milligram of phosphorus per liter, and over 8 milligrams of silicon per liter. The phosphorus content of the lake water during June, July, and August remained at zero and the silicon content of the lake water was 1½ milligrams per liter in June, a trace in early July, zero in late July, and a trace in August. Thus the phosphorus and silicon were being used up as fast as they became available

to the phytoplankton in the lake. Samples taken on September 6 showed 6 one-thousandths of a milligram of phosphorus, and one-half a milligram of silicon per liter. Plankton samples showed less plankton in the water than was present earlier in the summer. Thus some other factor, probably the amount of light, was acting as a limiting factor at this time, and was allowing the gradual accumulation of phosphorus and silicon in the lake water.

Other fish inhabiting this lake naturally have some effect on the population of young red salmon. Present in the lake are young silver and king salmon, a small population of young steelhead trout, cottoids, sticklebacks, and Dolly Varden trout. It is considered that only the two last-named species may have an important effect on the survival of the red-salmon fingerlings. The sticklebacks, due to their abundance, are possible competitors for food, and the Dolly Varden trout are predators. Dolly Varden trout were caught in a gill net, at all depths down to 52½ meters (175 ft.). Salmon eggs were found to be present in the stomachs of trout taken in depths down to 46 meters (151 ft.) indicating that these trout alternate between shallow and deep water in a relatively short period of time, or else that red salmon may spawn in deeper water than previously supposed. Adult red salmon were taken in the net in depths down to 41 meters (134 ft.) and appeared to be quite abundant in depths down to 24½ meters (80 ft.). Of the trout caught between July 19 and July 30, stickleback eggs and snails were the main articles of diet, salmon eggs making up only 7.5 percent of their food. Of the trout taken between August 17 and September 9, salmon eggs made up 35 percent of the diet, with sticklebacks and snails next in importance.

Trout take a heavy toll in the early spring when the salmon fry are migrating down stream into the lake. However, stomach contents of trout taken during the summer months showed very few remains of salmon fingerlings, none being found in the July samples, and only 1.2 percent in August and September.

Data on the returns from known escapements were collected, escapement and catch records were compiled, and scale samples taken throughout the season for the purpose of age determination. Complete returns from the 1929 spawning are now at hand with the exception of the few 7-year fish which will return in 1936. The 1929 escapement was 900,519 and the return per fish from this escapement will be approximately 1.6 to 1.0, as compared with 2.2 to 1.0 for the 1928 escapement and 1.8 to 1.0 for the 1927 escapement. There is considerable evidence toward the belief that these returns are below normal and are, in the main, caused by unfavorable environmental conditions existing in Karluk Lake during the time these fish were residents there.

CHIGNIK RIVER RED SALMON

This investigation was continued in 1935 on a much reduced scale. As in 1934 a temporary assistant was stationed at Chignik from May until October for the purposes of collecting fish scale samples, and of observing the commercial catches for marked fish. The data collected have been filed for future use.

PINK SALMON

The activities of this investigation in 1935, as in past years, were confined mainly to the study of the pink-salmon populations of southeastern Alaska. Although the pink salmon are found in practically all of the waters of Alaska they are most abundant in this section. The salmon populations that support this fishery spawn in hundreds of streams, varying greatly both in size and character of habitat. Hence it is believed that the fundamental facts secured from the study of the fishery in this section may be applied generally to the pink-salmon fisheries of Alaska. Dr. Frederick A. Davidson is conducting this investigation, assisted by S. J. Hutchinson.

Studies were continued on the factors responsible for the fluctuations in the abundance of pink-salmon populations that spawn in the stream at Little Port Walter, Alaska. A counting weir has been maintained in this stream during the past two seasons. In the summer of 1935, 6,075 pink salmon were tallied through the weir on their migration upstream to the spawning grounds. Samples of this run of salmon were taken at the weir throughout the migratory period. These samples were studied for the purpose of determining the sex ratio, fecundity, and racial characters of the pink salmon composing the 1935 population. Observations on the spawning grounds in the stream indicated a successful spawning of this population. During the entire year records were kept of the prevailing meteorological and hydrographic conditions that tend to influence the development and mortality of the brood. Since the study of the pink-salmon populations at Little Port Walter has been carried on for two seasons only, no returns have yet been secured from known spawning populations.

The pink salmon migrating into the stream at Little Port Walter were studied also from the standpoint of the physical and chemical changes that take place within the body during their spawning migration from the sea. This is a continuation of the cooperative study of this phase of the life history of the pink salmon that the Bureau has been carrying on for the past few years with the National Canners Association of Seattle, Wash. The results of this study provide information relative to the seasonal change in the market quality of the pink-salmon pack each year that is of primary importance to the canning industry. A preliminary report of the progress of this study up to 1935 was completed during the past year and was published as Investigational Report No. 33 of the Bureau.

Owing to the need for further information concerning the migrations of pink salmon through Clarence Strait in southeastern Alaska, a pink-salmon-tagging experiment was conducted in this area during the summer of 1935. The runs of salmon that migrate into Clarence Strait from Dixon Entrance are composed of different races that are bound for the spawning areas adjacent to the strait through the entire course of 130 miles. McLean Arm, which is approximately 8 miles above the junction of Clarence Strait and Dixon Entrance, was selected as the point for tagging. Through the courtesy of the Alaska Pacific Salmon Co., 1,900 pink salmon were tagged from their McLean Arm trap in lots of 400 and 300 each, during the weekly closed periods beginning July 27 and ending August 17.

This is the first of the salmon-tagging experiments conducted in Alaska that includes a series of consecutive taggings at one point. It is hoped by this method to secure a more detailed analysis of the migratory routes and parent localities of the pink-salmon runs that pass through Clarence Strait during the entire fishing season. The returns from this experiment have thus far amounted to more than 33 percent of the total number of tags placed on the fish. Since the pink salmon have a complete 2-year life cycle, there are two distinct populations in each stream; viz, those spawning on the odd years and those spawning on the even years. In view of this fact, it is planned to conduct a similar tagging experiment in Clarence Strait in the summer of 1936 to determine any differences that might occur in the migrations of the pink salmon that comprise the even year runs.

Although the native distribution of the Pacific salmon has been discussed from time to time by various icthyologists, no one has made a study of the environmental conditions in the different habitats in which these salmon are found. Furthermore, no attempt has been made to compare the environmental conditions found in the foreign habitats whither they have been successfully or otherwise transplanted, with the conditions in their native habitats. Such a study was started during the past season for the pink salmon and then extended to embrace all species of the Pacific salmon. It is hoped that this study will indicate some of the limiting factors that are responsibile for the geographic distribution of the salmon.

ALASKA SALMON FISHERY STATISTICS

There has been an ever growing need for an investigation dealing with the collection, compilation, and biometrical analysis of the daily catch records of the various types of fishing gear employed in the Alaska salmon fisheries. These records form the basic data for studies concerned with changes in the abundance and character of the salmon runs, and the competition between the various types of fishing gear. It is through such studies that the conservation of the salmon runs is assured for they provide the factual basis for the proper regulation of the fisheries.

Through a cooperative arrangement between the Alaska Division and the Divisions of Scientific Inquiry and Fishery Industries, funds were made available for the establishment of this investigation during the past year. Leroy Christey, who has had experience in fishery studies of this type, was employed to take over the duties of the investigation under the direction of Dr. Davidson.

In 1927–28 the daily catch records of a large number of salmon traps in southeastern Alaska were collected and studied for the purpose of providing information concerning the delimitation of the fishing districts and closed seasons for fishing in each of the districts in this region. This study was resumed in 1930 as a part of the pink-salmon investigation, and since then effort has been made to continue the collection of such records which have provided information for the further delimitation of the fishing districts and closed seasons for fishing in this region.

Since this study was carried on as a part of the pink-salmon investigation, time and funds were not available to make a comprehensive collection and study of all the trap catch in southeastern Alaska.

Hence one of Mr. Christey's first accomplishments in this new investigation was to make a thorough and exhaustive search for all data previous to 1930. Effort was made to contact all packing companies operating at the present time or in the past. While the catch records of some liquidated companies have been detroyed, sufficient data have been obtained to insure an adequate sample from 1907 to the present date. In addition to securing old records, it has been possible to contact the trap operators and impress them with the value of this work. The daily catch record was secured for each trap fished in southeastern Alaska in 1935.

As time permits, this work will be expanded to include other Alaska fishing areas. Considerable trap catch data have already been acquired for Prince William Sound, including complete returns for 1935. Some trap catch records also have been secured for Cook Inlet, and areas on the Alaska Peninsula. It is hoped that this work may be expanded to include the study of other units of fishing gear, especially the gill-net fishery of Bristol Bay.

HERRING

The herring investigation, under the direction of Edwin H. Dahlgren, was continued during the past year. The efforts of the investigation were again concentrated in southeastern Alaska, where the most productive and intensive fishery is carried on. The principal aims of the investigation are to delineate the areas inhabited by each of the major stocks of herring which comprise the total population of the area, to evaluate the relative abundance of each of these stocks, and to seek causes for the fluctuations in abundance which are known to occur.

The tagging program, begun in 1932, was continued. This tagging has a two-fold purpose; first, to delineate the areas inhabited by each of the major populations of herring; and second, to obtain a measure of the intensity of the fishery by considering the percentage of tags recovered. During the spring spawning season, tagging was carried on at Craig, on the west coast of Prince of Wales Island, and in the vicinity of Sitka, on the west coast of Baranof Island. As in the 1934 experiment, a large number of individuals were tagged in order to obtain more reliable estimates of the mortality imposed by the fishery. During a 3-week period 13,008 individuals were tagged at Craig; 20,157 at Sitka; 5,141 at Kalinin Bay, 25 miles north of Sitka; and 2,613 at Redoubt Bay, 15 miles south of Sitka.

The recovery of the tags affixed at Kalinin Bay and at Redoubt Bay, along with those affixed at Sitka show that these populations intermingle on the Cape Ommaney feeding grounds, and comprise a single stock of herring. The recovery of 86 tags affixed at the Sitka area, as well as 74 tags affixed at Craig, from Warren Channel, confirmed the findings of the previous year that there is an intermingling of Craig and Sitka fish in this area. On the other hand, failure to recover Craig tags in the Cape Ommaney region, leads to the conclusion that there is no counter migration of Craig fish to Cape Ommaney.

A method for the detection of the tags to supplant the present magnetic recovery system was tried out during the season—a method whereby the individual bearing the tag may be selected from the

large number of herring passing through the shore stations. The device is dependent on the bridge-circuit principle, in which the presence of the metal passing through the coils creates an unbalance which may be converted into a power impulse to eject the individual bearing the tag. The instrument proved feasible, and 66 tags were recovered during the season. The advantages of the device lie in the facts that it is possible to determine with greater accuracy the origin of the tags; to better evaluate the mortality imposed by the fishery; and by examination of the individuals bearing the tags, to determine the effect of the tags on the host.

There has always been a question as to how large a percentage of the population is taken by the fishery. The popular belief has been that only an immeasurable part is caught, and that the decline in abundance observed in certain intensively fished areas has been due entirely to the emigration of herring from that region.

Assuming that the tagged fish are distributed with the remainder of the population in a random manner, which appears to be the case from the fact that tags are returned from the various separate markings (throughout a greater part of the season), then the percentage recovery of tags gives a measure of the percentage of the total population taken. The figures herein given are admittedly in error, and represent the absolute minima of imposed mortality. There are three known sources of error which, at present, cannot be evaluated. First, there is probably a mortality caused by the tagging; second, there may be a loss of tags by their working out of the fish in life; third, there is a failure to obtain all the tags recovered by the fishermen due to inefficiency of the magnets, the loss of tags to souvenir hunters, etc.

Without considering these sources of error, however, it it evident that the fishery takes a considerable toll from the populations in the more intensively fished areas. That this is the case in the Cape Ommaney fishery is evidenced by the recovery of 101 or 4 percent of the Sitka tags in 1933; 482, or 4.4 percent in 1934; and 1,628 or 7.2 percent in 1935. The second main stock from which the fishery is drawing is that which spawns at Craig. For this fishery a 2.0 percent return (149 tags) in 1934, and a 2.3 percent return (233 tags) in 1935, indicates that this stock is not as intensively fished as is the Sitka population. These figures represent the recoveries of only one type of tag—others have been experimented with in an attempt to find the most suitable type possible.

For the past few years, 70 to 85 percent of the entire catch for southeastern Alaska has come from the Cape Ommaney region. There was a marked decline during 1935 in the catch per unit of effort in this area. This decline is accounted for by the failure of the normal increment of 4-year-olds to enter the catch. The catch for 1934 was dominated by the 4-year-olds from the brood year 1931; during that year they represented approximately 66 percent of the catch. The next year, however, owing to the failure of the new class of 4-year-olds to appear, this same 1931 brood furnished 89 percent of the catch; while the 1932 brood year, entering the catch for the first time, constituted only 3 percent of the catch. Thus the 5-year-olds, a class which had already been subjected to intensive fishing during one season, and suffered the inroads of

natural mortality, was not sufficiently abundant to maintain the catch on a high level of abundance.

With the spawning areas contributing to each feeding area known, it will be possible to estimate the abundance, and the size composition of the catch to be expected during the following season, by sampling the age composition of the spawning population during the spring. Thus, for the Sitka population, unless the new recruits entering as 4-year-olds in 1936 are relatively very abundant, the present low level of abundance may be expected to continue. This information will prove invaluable in providing for a stabilized fishery by permitting the formulation of regulations to spread the fishing intensity over the populations best able to withstand the strain.

INVESTIGATION CONCERNING THE PROTECTION OF MIGRATORY FISH AT THE BONNEVILLE DAM

Satisfactory progress has been made in the problem of providing suitable fishways at the Bonneville Dam. The work has continued under the direction of Harlan B. Holmes, assisted by Henry F. Blood, both of whom have had the temporary assistance of other biologists and engineers. The work has been conducted in close cooperation with the staff of United States Engineers and the State fish and game departments. The program and results of the first year's activities are briefly related in Progress in Biological Inquiries, 1934.

Formal recommendations were submitted to the War Department by the Commissioner of Fisheries in August 1934. After prolonged consideration the War Department approved a plan of fishways that for the greater part followed the recommendations of the Commissioner of Fisheries. Some features that the Bureau's staff had not considered essential were added. The collecting systems for attracting and directing the fish to the fishways in the main channel were materially reduced.

The detailed designing of the fishway is being done by the staff of United States Engineers. The staff of the Bureau of Fisheries has remained in close contact with the Engineers, and has found occasion to offer suggestions.

The progress of construction of the dam has been carefully followed with the view of assuring the free passage of fish during the period of construction. Although the skeletal structure of the powerhouse, which obstructs one channel of the river, and the base of one-half of the spillway dam, which will obstruct the main channel, are nearing completion, as yet there has been no interference with the passage of fish. It was anticipated, however, that temporary fishways will be required during the latter stages of construction. A study of the anticipated condition has been made and temporary fishways have been designed.

An extensive study was made of the injury to fish in passing through water turbines. Preliminary results of the investigation indicate that there is a tremendous variation in the conditions presented by different plants, with the result that some certainly could not be passed by even the smallest fish, whereas others may cause little or no injury. The Bonneville turbines are judged to approach

the latter. It therefore has not been considered necessary to install means of preventing the seaward migrating fingerlings from entering the turbines.

A study also was made of means of directing the route of travel of migrating fish in places such as the rapidly flowing water discharging from the spillway gates and power wheels. Particular attention has been given to the electric fish diverter. The nature of electric fields produced by various means of applying electricity to the water have been studied in the laboratory. The more favorable of these soon are to be applied in field tests.

SHELLFISH INVESTIGATIONS

PAUL S. GALTSOFF, *in charge*

The scope of the shellfish investigations was greatly enlarged by a special appropriation of $100,000 for the study of oyster pests, and the development of practical methods of their control in the Atlantic and Gulf States. The investigations on oyster and hard clam culture were continued in the waters of New England, South Atlantic States, and Puget Sound. A special allotment of $20,000, to be spent over a period of 18 months, was provided by the P. W. A. for a study of the failure of oyster culture in York River, Va., allegedly caused by pulp mill wastes. All the work has been carried out by the regular staff of the Bureau of Fisheries augmented by 20 temporary investigators, and 50 assistants whose period of employment varied from 3 to 9 months. Splendid cooperation was received from the various States, the P. W. A., and transient rehabilitation camps which supplied about 110 relief laborers for the field investigations.

OYSTER-PEST CONTROL PROJECT

The oyster-pest investigations comprised three major problems: (1) the starfish infesting the waters of New England and the North Atlantic States; (2) the drill, in the Delaware and lower Chesapeake Bays and occurring as far south as the Gulf of Mexico; and (3) the so-called leech, the recent outbreak of which has wiped out extensive areas of oyster producing bottoms in Florida. The problems of the destruction caused by the boring sponge and the borer, although of lesser importance, were also included in the program.

Practical methods that can be used by the oyster industry for the control of these pests must be based on a thorough knowledge of their life histories, and an understanding of their habits and activities. The applicability of control methods must be determined by large-scale experimentation.

In order to provide for efficient management of these investigations the entire Atlantic and Gulf area has been divided into sections with centers at Woods Hole, Mass.; Wickford, R. I.; Milford, Conn.; Bivalve, N. J.; Solomons, Md.; Beaufort, N. C.; and Apalachicola, Fla.

New England section.—Under the direct supervision of Dr. Galtsoff, studies of the starfish and drill along the Massachusetts coast were begun in June. Surveys were made to determine whether the

sudden appearance of large numbers of starfish is due to invasion from other territories or to the increased propagation of the local stock. Both field and laboratory work were carried out by Dr. K. S. Rice, Charles F. Reppun, and George Mishtowt.

There is no indication that starfish migrate during cold weather, their distribution over the bottom of Buzzards Bay being more or less constant with only small changes during the various seasons. The greater concentrations were found on the New Bedford side near the head of Buzzards Bay. The comparatively small number of starfish now found in the bay is perhaps due to the combined efforts of various town and State authorities who, with the help of Federal relief grants, succeeded during the past 2-year period in removing 173,300 bushels of starfish, or about 52 million adult organisms.

From laboratory experiments on the chemical control of this pest, in which 22 various inorganic substances were used, it seems evident that from every point of view, copper sulphate is the most satisfactory poison for killing starfish. In comparative ease of application, low cost, small effective concentration, rapid diffusion, and quick action, it is superior to other toxic substances that can be used in the sea. Under laboratory conditions it was found to be effective in great dilutions in killing starfish. Experiments were made to develop a copper-glue compound jelly which, placed on an oyster bed, would slowly diffuse, creating for a short time a concentration of copper sulphate sufficient to kill starfish, finally clearing itself completely, leaving none to injure the oysters. Earlier work with copper showed that its combination with a protein in order to produce a slow diffusion in water is lethal to starfish, but harmless to oysters within the time limits chosen. However, further experiments will be required in order to ascertain the most favorable concentration for practical purposes.

During the summer laboratory studies were conducted on the feeding habits and oviposition of the oyster drill, *Urosalpinx*. It was found that oysters, both young and adult, mussels, scallops, clams, barnacles, and some other mollusks are all used by the drill as food. *Anomia*, however, is never attacked. It appeared that barnacles are the favorite food.

Experiments in trapping drills on the rocky bottoms in the Woods Hole section proved unsatisfactory because the barnacle-covered rocks seemed to provide such an abundance of food that the drills could not be attracted by bait.

Laboratory observations indicate that there may be some correlation between the number of egg cases laid, and the amount of food available.

Attempts to poison drills with copper sulphate were entirely unsuccessful until dilute solutions were used that permitted the drills to remain open and active. This was found effective as a lethal agent when employed for a protracted time. Dilutions of copper sulphate of 0.3 parts per mille were effective in 18 days.

A survey of the Narragansett Bay, R. I., region was carried out by J. J. Hellewell with the cooperation of the Rhode Island State College which offered its laboratory facilities at Wickford, R. I., Dr. Charles J. Fish, who assisted in inaugurating the project, and

the State Commission of Fish and Game which provided a laboratory space at the State lobster hatchery at Wickford, R. I.

From the beginning of the work in July until its close in February, two extensive cruises were completed and many trips made, covering 150 stations, which, within the limits of the bay were established 1 mile apart, and at a distance of 4 miles apart in the sound. Observations consisted of dredging for starfish, recording data on temperature, salinity, depth, and the character of the bottom.

The October survey of these waters showed the starfish population to be concentrated in comparatively large numbers in two rather restricted localities near the headwaters of the middle passage. Weekly observations to detect the possible movements of starfish failed to show changes in their distribution and at the end of January the ranges of the two concentrations were much the same as in October. There was no indication of invasion of starfish from outside waters. Measurements of the starfish obtained from the two localities showed that those found nearest the headwaters of the bay (possibly an earlier seasonal production) averaged significantly larger, although the two localities were separated by a distance of only a few miles.

Winter studies show that as the temperature approached the winter minimum there was a cessation of growth, and a reduction in the rate of feeding of specimens kept in a live car. The size of these experimental animals in December coincided exactly with the mean of the stock from which they were obtained in October, indicating that the live-car records probably approximate normal conditions. As the difference in the mean size of the two groups has remained the same it is thought that the smaller group represents later production in the lower bay where seasonal warming is slower than in the headwaters, and that this group will mature and spawn at a smaller size.

The Oyster Laboratory at Milford, Conn., was the center of the investigation on the life history, biology, spawning, setting, and the migrations of starfish. The work was carried out by Dr. V. L. Loosanoff with the assistance of J. C. Lipsett, E. J. Larson, R. Nauman, A. Kammeraad, J. Piaat, R. B. Burrows, and H. Beard, and in cooperation with the Connecticut Shellfisheries Commission, which generously supplied the State boat *Shellfish* for the work in Long Island Sound.

The first survey covering 141 stations in the Sound was made in May, and was repeated during September and December. Results of field observations made during the spring, fall, and winter, show that starfish are practically limited to the shore regions of the Sound, although opposite New Haven and Bridgeport they extend some distance out into deeper waters. On the Long Island shore there are gaps at each end of Smithtown Bay and at two other eastern points where starfish appear to be absent. The longest shore gap however, is on the Connecticut shore from the Connecticut River to Guilford. Considering only the 43 stations where starfish were found, 93.4 percent in the first survey, 85.8 percent in the second, and 79.0 percent in the third, occurred in less than 40 feet of water, the greatest number being found at depths between 20 and 39 feet.

No correlation has been noticed between either the temperature or salinity of the water and starfish distribution, but the distribution is practically limited to those areas where shells are present on the bottom. Shells were found at 110 of the 141 stations, 89.9 percent of the starfish population being confined to these shell-covered areas. The greatest concentration of starfish was found in the extreme western part of the sound on the Long Island side on abandoned oyster beds, and bottoms covered with dead shells. Results of the surveys are of considerable practical importance for they disclosed the presence of great numbers of starfish on bottoms which are neglected by the oystermen.

Although a few specimens of *Asterias vulgaris* and *Henricia sanguinolenta* were found, *Asterias forbesi* is by far the predominating species of starfish found in this region.

Throughout the year the majority of starfish taken were of medium size, 2 to 5 inches in diameter, the size distribution being markedly similar for all surveys. The slight increase in the proportion of small starfish found in the winter survey is due to appearance of the 1935 crop.

Although field surveys have demonstrated a certain stability in the starfish population of this area, a direct attempt to study the movements of starfish seemed to be desirable. After experiments had shown all forms of tagging to be unsuccessful, a method of vital staining was developed and successfully employed. On November 19, approximately 15,000 starfish stained with nile blue sulphate were released at a known point in the sound. Since then extensive mappings have shown that migration is evidently slow, as in 2 months the most distant blue starfish were found only about one half a nautical mile south and west from the point of release. Five months later the starfish were still holding the blue color although a few were somewhat faded.

Laboratory studies on the condition of starfish gonads showed that in November there is an increase in gonad size, apparently in preparation for next year's spawning. In Long Island Sound the gonads appear to be mature before January, while near Woods Hole, Mass., maturity is not reached until late February or early March. It has been found that *A. forbesi* spawns when the temperature of the water reaches 20° C, provided the gonads are mature. Spawning in Long Island Sound first occurs about June 26–28, and continues until August 20.

Studies of the development of the larvae under laboratory conditions showed the larval period lasts 21 days at an average temperature of 20–21° C. Setting continued from July 15 until September 9, taking place at depths from mean low water to 70 feet.

A protozoan parasite, *Orchitophyra stellarum* Cepede, has been found in the gonads of the male *Asterias forbesi*, occurring in about 1 of every 15. It causes a great reduction in the number of spermatozoa in the follicles of the testis, often inducing total sterility. Work is now in progress to study the life history of this organism and its mode of infecting starfish.

New Jersey and Delaware Bay section.—The principal aim of the Bureau's work in New Jersey is the control of the oyster drills,

Urosalpinx and *Eupleura*, which constitute a serious menace to oyster production, causing a loss to the Delaware Bay oyster industry of approximately $1,000,000 a year.

Headquarters were established at Bivalve, N. J., with a field station at Cape May, N. J., where the State of New Jersey maintains an oyster experiment laboratory. Still another station was in operation during June, July, and August at Barnegat Bay, N. J., where studies were made on the activities of the drills with relation to changes in environmental conditions. The cooperation of the State of New Jersey, both by a generous offer of laboratory and office facilities, and by the use of its personnel and equipment, made possible a much broader and a more thorough study on the biology of the drill and the methods of its capture than would have otherwise been possible.

The work was carried out in cooperation with Dr. Thurlow C. Nelson, by Dr. Sizer, J. B. Engle, and H. H. Haskin. The State W. P. A. branch generously cooperated with the Bureau of Fisheries project by assigning 10 relief laborers for the construction and handling of drill traps, and by providing the boat for trapping experiments. Because of the seriousness of the drill problem in Delaware Bay, the work was carried out throughout the year and valuable information was recorded on the behavior of the drills during the winter months.

Two methods of controlling drills were attempted in Delaware Bay. One was the use of a chicken-wire bag trap that could be hauled to the surface at regular intervals, making use of the habit of the drill to climb upon any elevated portion of the bottom to feed and lay eggs. By using 3,500 traps for a period of 6 months, a total of approximately 1,300,000 drills were caught. To attempt control on a commercial scale, traps were concentrated in areas where tests showed the densest population. The traps were baited with young oysters and rebaited as often as needed, about once a month, and attached by snoods to a line of copper oleated rope, about 50 traps to a line. Four to six of these lines were placed at a station and tended weekly.

The other method of control developed during the course of the investigation consisted in dredging the bottoms with a drill dredge, especially designed to make it economical and available to the commercial oysterman. It is operated practically the same as an oyster dredge.

The combination of trapping with wire bag traps and the use of the drill dredge is considered a practical and efficient means of oyster drill control for Delaware Bay.

Since the knowledge of the life history and behavior of any destructive animal is essential for the operation of control measures, a comprehensive study was made of the habits, migration, and propagation of the drill.

A series of experiments was conducted on the migration of drills under varying conditions of temperature, salinity, and bottom. Results showed that drills are influenced in the direction of their migration by the position of food, that they move at a rate of at least 150 feet in 48 hours in the direction of food, and against prevailing currents. These migrations were performed over a bottom of loose sand and mud devoid of oysters or shells. The drill

proved to be active over the wide pH range of 6.5 to 9.1. At the acid and alkaline extremes a slowing up of activity was apparent.

Observations made in the laboratory during the winter months on the effects of temperature on drill movement showed some locomotion even at the low temperature of 2.2° C. The rate of feeding and consequently the destruction of oysters by the drills increases with temperature. The interval between feeding periods varies from 5 to 12 days. One drill will destroy, on the average, 0.34 oyster per week during the summer months, this estimate being lower than that reported at Beaufort, N. C. The salinities and temperature in New Jersey waters are somewhat lower than those at Beaufort, but this would probably not entirely account for the appreciable difference in rate of destruction at the two places.

Below a salinity of 10 to 12 parts per mille, the drills are inactive in boring the shells of oysters. Above this critical point there is no appreciable change in activity with the increase in salinity. Salinities between 10 and 15 and 30 and 35 reduce vitality of drills, while life cannot continue in salinities below 10 and above 35.

As a result of winter observations the following conclusions can tentatively be drawn: (1) Drills do not burrow in the mud during the cold period; (2) they do not seek cavities or empty shells as a place to hibernate; (3) they become dormant during extreme low temperatures (2.2° C or lower) and remain on the surface of the bottom.

Experiments using bivalves of equal ages as bait failed to show that the drills select those having the thinnest shells. If mussels (*Mytilus edulis*) whose shells are thinner than those of oysters are placed in a trap along with oysters as bait, the drills will attack the mussels first. It has been shown, however, that this preference is not owing to the thinness of their shell but to the fact that the meat of the mussel is preferred to that of the oyster. Consequently, mussel bait is twice as efficient for catching drills as oyster bait. Drills prefer the young spat to 1-year-old oysters, a reaction due not to the thinness of the shell, but probably to a difference in the chemical nature of the exudations of oysters of different ages.

Urosalpinx and *Eupleura* have been found to be equally destructive, although the latter is much more active in oviposition. This fact is especially important in view of the rapidly increasing ratio of numbers of *Eupleura* to *Urosalpinx* on the New Jersey oyster beds.

Urosalpinx cinerea deposits an average of 8 eggs per case and *Eupleura* sp. lays an average of 22 eggs per case. The bimodal frequency curve obtained for the number of *Eupleura* eggs per case indicated the possibility that two distinct varieties of snails of this genus were encountered. Further work will have to be done before this problem is solved. No significant variations in the number of eggs per case as related to salinity are apparent.

It has been found that adult drills can survive under environmental conditions in which they cannot reproduce. Drills placed in a trap and kept for a month in water where at low and high water the salinity varied from fresh water to 7 or 8 parts per thousand but frequently remained at or near the zero point throughout the entire tidal cycle survived, although no oviposition took place after the first week.

As noted previously by other investigators, not all of the eggs deposited develop into young drills. Study shows that approximately one-half of the eggs laid in the capsules fail to mature. Some develop into abnormal embryos and are eaten by the normal ones.

Direct evidence of cannibalism has been observed among adults, the animals having been drilled amid an abundance of oysters so that starvation conditions could not have been responsible for the attacks.

Urosalpinx may undergo its embryonic development in as short a time as 21 days. The fact that the egg cases under consideration were allowed to develop in their natural environment where the bottom temperature varied between 23.3 and 29.1° C. is stressed emphatically for it probably affords the explanation of the much shorter time than the 40 days in laboratory tanks at comparable temperatures, reported by another investigator as the time required for hatching. It has also been found that as many as 53 days may be required to complete development.

Middle and South Atlantic section.—Due to reports that the boring sponge, presumably *Cliona celata*, was a definite menace to oyster culture in Maryland waters, the Bureau undertook an investigation, assigning Dr. N. A. Wells and Dr. M. Old to study this problem. Through the cooperation of the University of Maryland, laboratory facilities were made available at the Chesapeake Biological Laboratory at Solomons, Md.; and a boat and captain were provided by the Maryland Conservation Department.

During the summer representative oyster beds in the Maryland waters of the Bay and all the major beds in the Potomac and Patuxent Rivers were surveyed. As the investigation progressed it became evident that practically all of the Maryland oyster-producing beds were free of *Cliona celata*, but many of them were infested to a greater or lesser extent with *C. vastifica*, another species of the same genus which had never been considered of importance as an oyster enemy. At only 2 of the 63 stations was *C. celata* found on living oysters. At one other station both *C. celata* and *C. vastifica* were found on shells, while the sponge at other stations was found to be *C. vastifica*.

Since there were no traces of *Cliona celata* at any salinity below 15.75, it is thought that this species will not live in a salinity below 15 parts per mille, but in order to substantiate this observation, further investigation is necessary.

The study of the distribution of *Cliona vastifica* shows that the highest percentage of infestation occurs between the salinities 11 and 13 parts per mille, although *C. vastifica* infestation is not necessarily at its highest peak wherever this salinity range is found. The lowest salinity in which this species is found appears to be 10 parts per mille while the upper limit has not yet been determined.

Heavy set and consequent overcrowding produces perfect conditions for spread of infestation. Because it is not unusual to find a large clump of oysters in a heavily infested area, entirely free of sponge, it is thought that the principal method of transmission is vegetative. In the laboratory gemmules of *Cliona vastifica* were demonstrated, occurring in every case in the marginal perforations and not in the older excavations. Among oysters taken from the

anchor chains of ships in the Patuxent River and undisturbed for many years, only 3 percent were infested, pointing to the insignificance of larval attachment.

Although heavy infestation weakens the shell, in some cases rendering the oysters unfit for market, in the opinion of some of the oyster packers and planters the sponge does not adversely affect the oyster in these waters. This does not prove, however, that the boring sponge is not a menace in other localities, particularly in the South Atlantic States where its destructive power may increase with the increase in mean annual temperature.

The work in the Middle and South Atlantic States carried out under the direction of Dr. H. F. Prytherch by William Hagen, Lloyd Garris, K. E. Johnson, G. R. Lunz, Jr., and assistants, consisted in large scale drill trapping experiments in the region from Chincoteague, Va., to Cape Charles, Va., where estimated damages caused by the drills amounted to over $150,000 annually. Also, comprehensive surveys of the distribution of oyster pests were made in the lower Chesapeake Bay and in the waters of North Carolina, South Carolina, and Georgia.

Through Paul B. Murphy, director of the Fort Eustis Camp for Transients, the services of approximately 100 transient laborers were made available for routine operations. A temporary field camp was established at Chincoteague and the U. S. S. *Kittery*, a 10,000 ton steamer, was anchored in the Onancock Harbor for use as a station ship. Six power boats were used to transport the crews from these locations to the oyster beds, where collections of drills were made by the use of traps in the case of deep-water beds or by hand-picking on exposed tidal flats.

Small wire bags baited with seed oysters, similar to those employed in New Jersey, were used. Traps attached in groups of 25 to a heavy rope line at intervals of 10 feet were fished once a week and the drills which had entered to search for food or to deposit their egg cases on the shells of the seed oysters were removed by vigorous shaking into containers aboard the boats. Experiments were carried out to determine the most effective arrangement of trap lines for removing drills from a given area, and to protect planted beds against invasion of these pests from surrounding bottoms. Over an average period of 12 weeks, 3,744 traps of various designs were used.

Trial of various methods of trap arrangement showed that the most successful and least expensive procedure for removal of drills from a given area is to anchor one end of a 250-foot trap line in approximately the center of a 4-acre unit and shift the position of the line about 45° each week. The second time that this area was trapped by the same method, the collection of drills decreased over 60 percent, indicating that the previous circuit had caused a significant reduction in the number of these pests.

Drills may likewise be collected by using parallel lines of traps which may be left stationary or moved a few feet after each weekly fishing, but this procedure involves a greater amount of labor, material, and time than the circular method. The results indicate that the use of 25 traps per acre on cleaned bottoms in Chincoteague Bay will remove virtually all of the drills in approximately 18 weeks.

Comparison of results with traps containing seed oysters and those containing clam and oyster shells showed that the former are seven times more efficient for catching these pests. A total of 80,838 drills of both species were removed from 60 acres of oyster beds, by hand picking, on the tidal flats at Wachapreague and vicinity.

Beds that have been cleaned and replanted with seed oysters can be protected against invasion of drills from surrounding bottoms by leaving an unplanted zone, approximately 20 feet wide, around the replanted area and surrounding the outer edge of this zone with a continuous line of traps set at 5- to 8-foot intervals. This method when tested on a commercial scale, showed an average collection of 5,760 drills per 25 traps over a period of 8 weeks. Subsequent examination of the seeded area showed an almost complete absence of drills, thus indicating that trapping operations of this type are of practical value for the protection of oyster beds.

It is clearly evident that the drill is a serious oyster pest, of such economic importance as to justify the immediate adoption and extensive application of control measures of the type outlined by the present investigation.

Two species of oyster drills occur in this region, namely *Urosalpinx cinerea* and *Eupleura caudata*, the former being considerably more numerous and destructive to oysters, comprising over 78 percent of the number collected. Prolific reproduction of *Urosalpinx* was observed in the heavy deposition of egg cases during June and July and the more or less continuous spawning of this species over a period of 7½ months. Egg cases of *Eupleura* were found in only three instances in numerous examinations of natural and planted beds.

Studies of the distribution, abundance, and possible control of oyster pests in the principal beds in Pamlico, Core, and Bogue Sounds and their tributaries in North Carolina were conducted in cooperation with the North Carolina Department of Conservation. In Core and Bogue Sounds where the salinity is high, ranging from 27.16 to 35.61 parts per mille, the destruction of 14 to 68 percent of spat and seed oysters by drills and 60 to 90 percent of adult oysters by boring sponge, was observed on beds located below low water mark. Drills were found to be most abundant on public beds in the vicinity of Harbor Island and Atlantic where 13 to 22 specimens were collected per bushel sample. By means of trapping operations a total of 10,755 drills were removed from these areas over an average fishing period of 4 weeks. In one locality an unusual catch of 3,238 drills was made with 100 traps in 1 week, of which approximately 94 percent were young specimens measuring from 3 to 14 millimeters in length. This particular area had been restocked the previous year with culled seed oysters from drill infested beds near Portsmouth, thus demonstrating how transportation of egg cases of this pest may cause its spread to other beds.

Field investigations were conducted from June 15 to October 15 along the western shore of the Chesapeake Bay in cooperation with the Virginia Commission of Fisheries. Observations at 245 stations showed the drill to be abundant throughout this region. An average of 9 drills and 35 egg capsules were found per bushel of oysters. Drills were most numerous in lower portions of the bay and rivers

where the salinity ranged from 19.05 to 24.25 and were absent in salinities lower than 15 parts per mille. A total of 1,527 drills were collected, 70 percent of which were alive, the others having been killed by the freshets of the previous winter. Eighty-three percent of the total were *Urosalpinx cinerea;* and 17 percent, *Eupleura caudata.*

In South Carolina, in cooperation with the State Board of Fisheries, a general survey of oyster pests in the coastal region from the Santee River to the Savannah River was conducted for the Bureau by G. Robert Lunz, Jr., of the Charleston, S. C., Museum. Samples of oysters collected at 132 representative stations show that the boring sponge and drill are the principal enemies of economic importance in this section. Over 41 percent of all oysters collected were infested with the boring sponge, particularly the more common species, *Cliona celata*, which at many stations showed prolific growth and honeycombed the shell of from 80 to 100 percent of the oysters. Serious shell injury by this pest is limited almost entirely to beds lying below low tide level in the more saline areas near the inlets, where oysters on both natural and planted beds rarely survive for more than 2 years because of sponge attack.

Damage by drills is limited for the most part to spat and small seed oysters occurring chiefly in a zone extending from 1 foot above low water mark to the bottom of the bed. Other pests found occasionally are the starfish, conch, and borer, none of which were found to be causing serious damage during the present survey, In several localities a heavy growth of common anthozoan coral, *Gorgonia*, was found on beds below low tide level where it apparently causes indirect injury and smothering of oysters by reducing the circulation of water and increasing the deposition of mud and sand.

During the period from September 15 to November 15 a general survey of the oyster pests on the Georgia coast was conducted in cooperation with the State department of game and fish. Observations made at 141 stations extending from the Savannah River to the St. Mary's River, show an abundance of drills on the natural beds, and an extensive and severe infestation of oysters by the boring sponge. Studies of drill distribution in relation to salinity show their presence at salinities from 10.4 to 30.6, the maximum abundance occurring in salinities from 24.3 to 27.7, or an average of 18 drills per sample. The boring clam, *Martesia*, was found to be a pest in this region, infesting the shells of 24 percent of the specimens examined, but in no case was it so abundant as to cause serious weakening or injury to the shell. Specimens of the borer, *Purpura*, and the conch, *Busycon*, were collected at 27 stations in salinities ranging from 17.6 to 30.4, but were not sufficiently numerous or destructive to oysters as greatly to reduce their production in this region.

Studies of the parasitic microorganism found in oysters in Louisiana, Virginia, and North Carolina were continued at the Beaufort laboratory by Dr. H. F. Prytherch. An improved technique was developed whereby rapid examination of the fresh tissues of spat and adult oysters could be made to determine the degree of infection by this protozoan, and the various stages in its life history. Examinations of over 750 spat collected during the period from March to December, show that the heaviest infection of the oyster tissues oc-

curs during the summer and fall months, and is followed by rapid reproduction and spore formation in the body of the host. Although the parasite has not yet been identified, its position as a member of the class Sporozoa has been confirmed by Dr. R. R. Kudo of the University of Illinois.

South Atlantic and Gulf section.—Oyster-pest investigations were undertaken on the Gulf coast, covering the inshore waters of Florida, Alabama, and Texas. Previous surveys and reports from members of the fishing industry showed that the most destructive pests in this section are the borer, *Thais*, and the leech, or wafer, *Stylochus*. Other pests associated with these, but whose relationships as commensals or enemies are undetermined, are the boring sponge, *Cliona;* boring clam, *Martesia*, and barnacles and mussels. The most serious damage was reported from Apalachicola Bay, Fla., and it was therefore decided to make this area the headquarters for the Gulf investigations. Separate surveys were made in Texas and Alabama.

Owing to the unavailability of sea water in Apalachicola, it was finally decided to establish the laboratory at Indian Pass about 20 miles away, where electric power could be obtained and communication with Apalachicola was possible by road. The construction of the laboratory was begun on May 20. The site was furnished gratis by its owners, the Lagoon Co., and the materials were supplied by the State department of conservation through the cooperation of Commissioner G. W. Davis. By July the building was ready for occupancy. It is of frame construction, consisting of a main laboratory and six smaller rooms, and a basement for pumps, storage, garage, etc. In August the salt water pump was installed and by September the laboratory was supplied with running sea water. The floating equipment of the laboratory comprises a large and a small skiff, and a cabin cruiser with accommodations for four persons.

Before the completion of the laboratory, field work was undertaken by R. O. Smith and G. Gunter on the study of the borer problem. Traps of aluminum insect screen, baited with large and small oysters and mussels, were set on oyster bars. This type of trap caught *Thais* on barren bottoms where no other food was available, but was inefficient where oysters were plentiful. Traps made of copper wire proved toxic to both oysters and mussels used for bait.

Chicken-wire cages were made to carry out field experiments on the rate of feeding of *Thais* and destructiveness of this gastropod in various salinities. The cages were placed on 6 different bars with normal salinities ranging from less than 10 to over 30. Unfortunately freshets brought all salinities down to less than 10 for a long enough period to kill all *Thais*, the experiment resulting, therefore, only in the proof that oysters can withstand a lower salinity over a longer period than can the borer.

Laboratory experiments have shown that *Thais* suddenly subjected to a drop in salinity of from 25 or above to below 10, survive about 2 weeks. However, if the change is gradual the borer will live several weeks without food even though the salinity be reduced to below 5. In any case, both field and laboratory observations show that *Thais* can live very well in salinities between 15 and 25 parts per mille.

In contrast to such borers as *Urosalpinx* and *Eupleura*, *Thais* rarely bores a hole, and has never been found to do so in the thick

part of a shell. Its mode of gaining entrance to an oyster is to cover the bill with its foot and under cover of this, rasp away the thin edge of the upper valve until a very narrow aperture is made. At present it is thought that a narcotic secretion is poured into the shell resulting in the narcosis and relaxation of the adductor muscle of the oyster. The presence of a large amount of purplish colored mucus found in attacked oysters along the frontal edge of the gills and the lack of mechanical means of holding the shell open during feeding seem to substantiate the observations, although further study of the problem is necessary. A *Thais* can kill and eat an oyster within 12 hours. In view of the relative ease and rapidity with which large oysters may be opened it is evident that the thickness of the shell is not a factor in the selection of food. Therefore, as shown by experiments in the field, trapping cannot be carried out successfully with baited traps.

Studies along this northwest coast of Florida show that, if 1935 was a normal year, spawning of *Thais* extends from late May to the early part of August, during which time temperatures are above 20° C. and salinities are over 20. There is a definite spawning migration, and egg laying is usually done by groups of individuals assembled in one place. Whenever possible capsules are deposited in masses on objects well elevated above the bottom. Each of these masses has been found to contain from 3,600 to 6,000 eggs. Development proceeds in the capsules for at least 7 to possibly 14 days.

The average size of the adults, both male and female, is 8 cm. Attempts to follow the rate of growth have so far been unsuccessful. Every area, from fresh water flats at the head of the bay to 5 fathoms out in the Gulf, was searched for young forms a number of times but out of several thousand specimens collected, less than half a dozen were under 5 cm in total length. It has been thought that last season was for some reason unfavorable for the survival of young *Thais*.

Beside the study of the distribution and habits of the borer, the field work in this section also included cruises for collecting hydrographic data for the practical purpose of obtaining a better understanding of the relationship existing between oysters, their enemies, and the various environmental factors involved. Hydrographic observations were confined to the oyster-producing areas of Apalachicola Bay, totaling about 130 square miles.

Although the laboratory is located in the pass between the Gulf and St. Vincent Sound there is a large difference between the maximum and minimum salinities even during the dry summer months. This wide range in salinities has a practical bearing on the oyster industry, for extreme changes from salt to fresh, or vice versa, render oysters unsuitable for the market. Oystermen frequently find it necessary to transfer operations from one locality to another in an attempt to locate oysters of marketable quality. It is believed that this situation might be greatly improved by setting aside suitable bottoms for the production of market oysters, while other beds would be used chiefly for seed production.

Examination of the oyster bars in this region has shown that the destruction of the large productive beds in St. George Sound has thrown an added strain on bars in other localities. The majority

of the bars supplying the market are badly overfished, the supply of cultch is inadequate, and unless additional bars can be brought into production, the present rate of fishing on producing bars will result in a steady decline in the size and quality of the shell stock.

Life history of the leech.—A study of the two species of polyclad worms or so-called leeches, *Stylochus inimicus* and *Eustylochus*, associated with the oysters of this region, and at times so abundant as to do damage, was carried out by Dr. A. S. Pearse and G. Wharton. *Stylochus* has been found at Bull's Bay in Charlotte County, Tampa, Crystal River, Port Inglis, Cedar Key, Apalachicola Bay, Port St. Joe, and Crooked Island Sound. It is more common in summer than in winter. *Eustylochus* is being described as a new species, having a wide range along the Atlantic and Gulf coasts, and found in all of the localities just mentioned in Florida. This species is apparently more common in winter than in summer along the Florida coast.

The anatomy of both species of oyster "leeches" has been studied in some detail. The largest specimens of *Stylochus* collected measused 48 by 28 mm, while those of *Eustylochus* measured 22 by 9 mm.

Stylochus is remarkably fecund. A single individual kept in sea water in a finger bowl in the laboratory laid 22,370 eggs. The leeches found in oyster shells in Apalachicola Bay were found to be brooding clutches of eggs numbering as many as 18,028. For development, a *Stylochus* egg requires from 9 to 15 days at summer temperatures, and hatches into a ciliated larva similar to those characteristic of leptoplanid polyclads. After a time it tends to creep about on solid objects, and when adult entirely ceases to swim. Eggs of this form were still being found on oyster bars as late as January 11.

Neither *Stylochus* nor *Eustylochus* have been observed to eat any food other than the bodies of oysters, though the latter is believed also to eat barnacles. Observations show that they bite holes in the oyster's body, usually attacking the gills first. An oyster invaded by a leech usually secretes a partition along its edge to shut out the intruder and sometimes succeeds in covering it over so as to incorporate it in the shell. An oyster occupied by a worm opens and closes its shell more often than under normal conditions.

Studies of the distribution of polyclads on the oyster beds in Apalachicola Bay at times showed more than 200 polyclads in a bushel of oysters. In general, *Stylochus* was most abundant where oyster bars were nearest the open sea; while *Eustylochus* was most abundant where mussels and barnacles are found; viz, close to shore or in inclosed lagoons. Polyclads such as these show considerable toleration to variations in environment, perhaps owing in part to mucus secreted abundantly when unfavorably stimulated. Low salinities undoubtedly cause their death. Eggs will not develop, and adults commonly do not lay eggs in salinities below 15 parts per mille and larvae have been killed in salinities as low as 13.9. When subjected gradually to progressively lower dilutions, the adults will live in a salinity as low as 6 parts per mille, *Eustylochus* enduring lower salinities than *Stylochus*. *Stylochus* endures considerable desiccation, reviving when immersed in sea water after a loss of 54 percent of its body weight.

Stylochus can survive in water which contains little oxygen. The effects of 23 chemicals on *Stylochus* in sea water were studied in an attempt to discover some substance which might kill the polyclads on oyster beds, but none of these has given promise of success. The larvae were less resistant than adults, but such high concentrations of poison were required to kill either that there seems little hope of controlling these pests by chemical means.

Texas.—During the summer of 1935 the oyster bottoms of the Texas coast were surveyed to discover the kinds and numbers of oyster pests present, and wherever possible to devise methods and make recommendations for their control. This investigation was carried out by Dr. Henry Federighi and A. Collier, with the cooperation of the Texas Game, Fish and Oyster Commission, who supplied the boat *Vivian*, which was converted into a laboratory and houseboat, and also the patrol boat *Eugene* and other floating equipment stationed along the Texas coast.

The survey, begun at Corpus Christi Bay and completed at Galveston Bay, followed very closely the Bureau's previous surveys in 1926 and 1931. Approximately 800 miles were covered during July and August, examinations being made of commercial reefs to determine the condition of the oysters, the salinity, temperature, character of the bottom, and the kinds and numbers of oyster pests present.

The most common oyster enemy in Texas, distributed from the Corpus Christi to Galveston Bays, is the common boring clam, *Martesia caribaca*, whose habit is to get a hold in an oyster shell and use it as a protective covering. In many cases it was found that a single oyster may harbor several hundred boring clams within its shell. Although it is probable this infestation has some effect on the growth and fattening of the oyster, it is impossible at present to state exactly what the effect is. Little is known concerning the life history of this pest.

Other pests found during the survey were the borer, *Thais haemastoma*, which does considerable damage in Louisiana and Florida; the common conch, *Fulgur perversa*, whose method of attack on oysters is still incompletely known; the boring sponge, *Cliona* sp., found only infrequently on the Texas coast, and probably of little significance; and the mussel, *Mytilus* sp., scattered here and there along the coast, and varying greatly not only from year to year but from season to season.

It was found that the tremendous destruction of the oyster beds in this section was due to the extraordinary increase in fresh water flowing from the flooded rivers of the Coastal Plain during May and June. In some areas there was a lack of live oysters due to the influx of the fresh water and its persistence over a period of time. In the northeastern part of Matagorda Bay, in past years the best source of oysters on the Texas coast, oysters have either been killed by the fresh water or covered with mud from the Colorado River, carried down into the bay since the removal of the dam.

INVESTIGATIONS ON OYSTER CULTURE

Long Island Sound.—Because of increased activities in connection with the oyster pest control investigations, the regular studies on oyster culture were greatly curtailed. A study of seasonal varia-

tions in the metal content of the oyster meats and its relation to environmental changes was carried out in Long Island Sound by Dr. P. A. Galtsoff and Charles Weber. Over 100 composite samples of oyster meats collected in previous years at the experimental oyster farm at Milford, Conn., were analyzed for copper, iron, zinc, and manganese. The results of the chemical analysis reveal interesting facts regarding the fluctuations of these metals in oysters taken from one locality. It has been found that copper is subject to wide and irregular fluctuations while the iron content remains almost constant. The manganese shows steady increase during the period of gonad development, and an immediate drop after spawning. More detailed studies showed that manganese is accumulated by the ovaries but not by the testes or other tissues. All the oysters were very rich in zinc, the content of which fluctuated between 5,500 and 13,700 milligrams of metal per kilo of dry meat.

Alabama.—At the invitation of Commissioner I. T. Quinn, chairman of the Alabama Oyster Commission, Dr. Galtsoff made a preliminary survey in November of the oyster beds in Mobile and Perdido Bays to determine the best areas in which to initiate a W. P. A. development program of the oyster reefs in Alabama. As a result of this survey James B. Engle was sent to Alabama in December by the Bureau to make a more detailed study of oyster cultural problems in Mobile Bay with the view of assisting the State in reviving the oyster industry.

The reefs north of Cedar Point were found to have only a sparse growth of seed oyster available for rehabilitation, being on the whole badly depleted, partly as a result, perhaps, of illegal dredging. As an alternate area for seed supply Dauphin Island was suggested, since in this region there are many small oysters in clumps which would break up during handling. In Bon Secour Bay the reefs were also found to be badly in need of reshelling, the shells found being pitted and disintegrating from age and decay. It was suggested that shucking houses use their discarded shells for this purpose.

In the shoals lying between Cedar Point and Little Dauphin Island, an area of 6,000,000 square yards of densely covered bottom, the oysters appeared to be overcrowded. Thus between 50,000 and 75,000 barrels of seed could be obtained from this area at present to the benefit of the beds.

A survey of conditions on reefs of western Mobile Bay showed a good quantity of seed in small clusters and singles, which could profitably be moved from this section to a bottom where there is less chance of spring freshets destroying the young stock.

In connection with these surveys an investigation was undertaken to determine the effect on oyster bottoms of opening channels into Dauphin Island Bay, now almost landlocked. It was concluded that resulting changes in salinity would probably not be seriously detrimental to marketable oysters, unless conditions throughout Mobile Bay and Mississippi Sound are bad. In any event, as a result of the exchange of waters and the consequent augmented supply of food organisms, oysters growing in those deepened regions should be superior in quality. They should also be benefited by the protection against adverse temperature which deep water affords.

OYSTER INVESTIGATIONS IN WASHINGTON STATE

Most of the work carried on at the Puget Sound Laboratory by Dr. A. E. Hopkins has been a continuation of the plan of study on the problems concerning the Olympia oyster, *Ostrea lurida*, and is inseparable from the general results obtained and recorded since the investigation was undertaken in 1931. The purpose of this investigation was to make a study of the factors influencing spawning and setting of the Olympia oyster in order to develop a system whereby oyster growers could be assured annually of an abundant supply of seed. Therefore, studies were made of spawning habits, larval life, and the attachment of the larvae.

Thermograph records of water temperatures taken continuously over a period of 5 seasons indicate that 13° and 14° C, the average temperatures of the water in which Olympia oysters begin to spawn in the spring, may not be called the critical temperature for some spawning takes place above and below this temperature range.

It has been found that after their discharge from the maternal brood chamber the larvae swim freely for a period of from 29 to 41 days, depending upon water temperature.

The relative number of spat caught daily per unit of cultch was obtained for each of the past 5 summers as follows: Wire baskets containing shells were planted throughout each season, allowed to remain in the water for a few days, and the collected spat counted. It has been found consistently that the setting of larvae occurs in well-defined periods directly correlated with tidal cycles. Typically setting is heaviest during a run of extreme minus tides. Experiments show that most of the larvae attach upon the flood tide, few at the ebb tide during this period. Very little setting occurs during neap tides. Thus, within certain limits, the waves of setting are predictable merely from the tide tables. On the basis of such results, oyster growers were advised as to the time to plant cultch for the collection of seed, and it is generally agreed that the industry has benefited materially by this assistance during the past several years.

Continued study of the effect of changes in salinity on the rate of feeding of the Japanese oyster have further shown these quantities to be directly correlated. When the salinity falls below approximately 13, the oyster appears to be unable to pump water. Above this level, within limits, the rate of pumping increases directly with salinity. These experiments provide the much-needed information about the effect salinity may have on transplanted oysters.

A study was begun on the spawning and setting habits of the Japanese oyster, which has recently become established on the Pacific coast. While the temperature of the waters in this State is in general somewhat too low for successful natural propagation of this species, it is evident that scientific investigations may show it possible for growers to produce their own seed instead of importing it from the Orient. In the summer of 1935 an investigation was begun to lay the foundation for a more extensive study of this problem during the next few years.

A matter requiring immediate attention is the Japanese oyster drill which, unfortunately, has been introduced into several waters in the State of Washington, and in one locality has done tremendous

damage. This pest is not subject to control measures effective in other sections of the country because of its different biological reactions. Even in the middle of December when the water temperature averaged 10° to 12° C, egg cases of this species were found containing all stages of developing young from early embryos to small snails ready to escape. A detailed study of this drill is essential not only for the benefit of the Japanese oyster, but also for the protection of the native oyster of the Pacific coast.

YORK RIVER POLLUTION INVESTIGATION

In October 1935, under a special allotment of $20,000 received from the P. W. A., the Bureau began investigations at York River, Va., to determine what effect, if any, the pulp mill wastes discharged at West Point, Va., have on the oysters of this region. Local oystermen reported that the oysters were in poor condition, that many were stunted and discolored, with shells so thin they could almost be crushed in the hand. Formerly the York River oysters were noted for their superior quality and especially prized in the New York market. Dr. N. A. Wells was in charge of the field work, assisted by Dr. W. A. Chipman, A. D. Hasler, and L. Garriss.

This investigation has consisted mainly in field and laboratory studies on the effects of various concentrations of pollutants on the survival of oysters, their physiology, rate of feeding, and on the accumulation of glycogen in their tissues under various environmental conditions.

A building was leased in Yorktown, Va., and converted into a laboratory with a running sea-water system. Labor as well as considerable construction material was provided by the Fort Eustis Transient Camp under the direction of Paul B. Murphy. The Virginia Commission of Fisheries cooperated in the project making available the *Marguerite*, a 65-foot Diesel powered boat.

After the first week in October field stations were established, water and oyster samples being collected at stated intervals for chemical analysis. Up to the end of the year, eight cruises have been made on the York River, and three on the Piankatank River, which was selected for control observations.

Due to the efforts of Mr. Richard Armstrong, Commissioner of Fisheries of Virginia, the State appropriated $500 to defray the expense of planting experimental beds of oysters in the York and Piankatank Rivers during the Bureau's pollution studies. Between November and early January, seven beds were planted in the York River and two in the Piankatank. Samples of oysters were taken at regular intervals from these beds and analyzed as to glycogen content, shell weight, shell liquor, etc. Water samples were taken at the same time for chemical analysis.

Observations thus far show that living oysters in the upper part of the York River, near the pulp mill, have shells that are extremely thin and soft. Since this poor condition indicates that something may be interfering with the normal metabolism of the oyster, experiments are being planned to study calcium metabolism. It is of interest to note here that this abnormal shell condition has not been observed to exist in any other river emptying into the Chesapeake Bay, or in the bay proper.

Examination of tissues in oysters from the upper part of the river show them to be more flaccid and transparent than those from the lower part; they have less meat and less shell per unit of total weight, have a higher water content, and lower glycogen content.

In order to obtain a satisfactory solution of the pollution problem in the York River it will be necessary to have a complete picture of physical, chemical, and biological conditions in the river at the present time, and as much of an historical background as possible.

For information concerning the past history of the oyster industry in York River, the investigators are dependent upon the willingness of oyster planters to state the changes, if any, in their yield of oysters before and since the establishment of the pulp mill. Since they have agreed to cooperate in this, it is hoped that these invaluable data will be available.

In connection with the York River pollution investigation experiments were conducted in the Washington laboratory to determine the effect of the pollutant from the York River on the rate of propagation of diatoms which comprise the food of oysters. Other experiments are being carried out to determine the effect of various mineral salts on the propagation of diatoms. Numerous experiments along this line are under way.

BIOLOGY OF THE QUAHOG (*Venus mercenaria*)

An investigation of the life cycle of the quahog clam was carried on by V. L. Loosanoff at Milford, Conn., where specially constructed tidal tanks permitted the physiological observations under conditions very closely approaching those of the natural environment. During the year, observations were made on the gonad development of the clam and its feeding activity.

Young clams, when only 0.6–0.7 cm long, collected on the clam beds of Long Island Sound near Milford, Conn., in October, were found to possess distinctly bisexual gonads with very strong male predominance. In the majority of cases fully ripe spermatozoa occupied the central part of the lumens, while small oöcytes and oögonia constitute the inner walls of the follicles.

In the middle of the summer, when the water temperature reaches the critical point, the ripe spermatozoa are discharged. Soon afterward two distinct types of individuals become distinguishable as definite males and females. In the males a second period of spermatogenesis begins in the autumn and continues at a reduced rate throughout the winter. In the spring, with the increase of water temperature, rapid branching of gonad follicles takes place simultaneously with increased rate of spermatogenesis. The gonads then have the typical male character of the adult. Spawning follows later in the summer, when the size of the shell has reached a length of 3 cm or more.

In those individuals destined to become females the lumens of the follicles remain empty after the spermatozoa are discharged. At the end of the initial male phase the gonad follicles remain distended with only a thin layer of undifferentiated cells and small oöcytes along the inner walls. In many cases numerous phagocytes invade the follicles and devour the degenerated male cells. Oögenesis begins in the early spring. In June and July the follicles

contain mature ova. The animals, formerly functioning as males, have now reached the stage of functional females.

The adults are, with few exceptions, of separate sexes. Among several hundred mature clams studied by means of serial sections only two cases of functional hermaphroditism have been observed. Nevertheless, examination of gonads of adult males reveals in almost every instance the presence of small oöcytes somewhere along the walls of the follicles. This may indicate the potentiality of changing the sex even in the adult condition, but so far there has been no evidence obtained to warrant such a conclusion.

Spermaries of adult males contain mature spermatozoa at all seasons of the year. When placed in sea water spermatozoa begin to swim actively in their typical spiral way after 2 to 3 minutes of quiescence. This simple experiment was tried at biweekly intervals throughout the year and always with positive results. The ovaries of adult females also contain large ova at all seasons of the year. In fact, little difference will be noted on superficial examination of samples collected in December and June. In both cases the follicles are large, distended, and filled with large oöcytes. In this respect the quahog differs remarkably from the American oyster, in which only shrunken follicles are found during the autumn and winter.

To study the effect of water temperature on the feeding of quahogs experimental animals were kept under natural conditions in large tanks in which the water was renewed with every tide. Each clam was immobolized by imbedding one of its valves in a mixture of cement and sand, and connected to the lever of a recording apparatus placed about 10 feet above. Each movement of the shell was recorded on the chart, and the temperature of the water was at the same time recorded by a thermograph. The clams were kept attached to the recording apparatus for varying periods of time ranging from 1 to 10 days. Usually the records of two clams were taken simultaneously. During these experiments the water temperature in the tanks varied from 0.0° to 28.0° C., thus covering the entire natural range of temperatures to which clams are subjected.

The hibernation of clams occurs when the water temperature is 4.9° C. or lower. Prolonged periods of opening of the shells and presumably active feeding and respiration proceeds at temperatures of 6.0° C. and above. This knowledge of the effect of temperature on the shell activities of the clam may add to a better understanding of several practical problems of the clam industry. Undoubtedly growth and fattening of clams, as well as development of sexual products, are dependent upon the length of time the shells are open because feeding can take place only during that time.

INVESTIGATIONS ON AQUICULTURE

H. S. Davis, *in charge*

Investigations on problems relating to aquiculture were continued along much the same lines as in 1934. Greater emphasis, however, was placed on field studies since it was believed that it will be impossible to utilize the products of our hatcheries to best advantage until we learn more about the various factors that affect fish in

natural waters. Our lack of information on these fundamental facts is the greatest obstacle with which we now have to contend in developing a scientific policy of fish management. Opportunities for field investigations by the Bureau of Fisheries have been greatly extended through a recent cooperative agreement with the United States Forest Service, which provides that waters in the national forests may be utilized by the Bureau for experimental purposes.

POND-FISH CULTURE

Owing to lack of funds for construction of ponds at the Leetown station, investigations in pond-fish culture during 1935 were again limited to experiments conducted by O. Lloyd Meehean at the Natchitoches (La.) station. These studies were a continuation of those begun in 1934 which were designed to determine the relative value of different fertilizers in pond culture. Although the ponds fertilized with cottonseed meal had produced, on the average, more food than those in which other fertilizers were used, the results of the 1934 experiments were not conclusive. For this reason a different method was adopted in 1935. Instead of keeping the amount of fertilizer per unit area constant, and varying its composition in each pond as was done the previous year, the quantity of fertilizer was varied, the composition kept constant, and the length of the fertilizer period extended. In all cases cottonseed meal was used as a fertilizer.

It was found that the average weight of bottom organisms was greatest in ponds that received the smaller amounts of fertilizer. The data indicate that under conditions at Natchitoches a weekly application of about 25 pounds of cottonseed meal per acre is sufficient to maintain fertility.

It was found that in general an increase in the production of bottom organisms resulted in a corresponding increase in the production of bass up to about 105 pounds of fish per acre. After this point was reached further increase in bottom organisms had little effect on the production of fish.

Carbon and nitrogen determinations were made of the plants found in the ponds. These studies showed that the ponds produced from 3.86 to 6.81 tons (dry weight) per acre of vegetation. Furthermore, the equivalent of 189 to 282 pounds of nitrogen is tied up in the vegetation in an acre of water during the season, in other words, as much nitrogen as is found in 1.39 to 2.08 tons of 36 percent cottonseed meal. These results indicate the extent of the loss in food elements when large amounts of vegetation are removed from a pond as is the common practice in pond culture.

TROUT CULTURE

Feeding experiments.—Feeding experiments at the Pittsford, Vt., station during 1935 were confined to tests of a new food, sold under the trade name of "Egg-Glo", which has been highly recommended as a trout food by a number of fish culturists. It was found that on a diet of 30 percent "Egg-Glo" and 70 percent beef liver, rainbow fingerlings made a considerably slower growth than a fish on either a diet of 30 percent salmon egg meal and 70 percent beef liver, or a

straight diet of beef liver. The mortality, however, was low and practically the same as in the lot fed beef liver only. The results with yearling rainbow trout were practically the same as with fingerlings.

In order to compare the value of seal meal and salmon-egg meal in the diet of trout, two lots of rainbow fingerlings, at the Leetown, W. Va., station were kept on experimental diets from September 23 to December 18. One lot was fed a ration composed of 60 percent beef liver and 40 percent seal meal while for the other lot salmon-egg meal was substituted for seal meal. At the end of the experiment the lot fed the seal-meal combination had gained 380.78 percent in weight while the lot fed the salmon egg meal combination had gained only 274.09 percent. The mortality was 10.2 percent and 16 percent respectively.

Selective breeding.—Breeding experiments designed to develop superior strains of trout were continued along the same lines as in previous years. Eggs from 48 selected pairs of brook trout were incubated at the Pittsford, Vt., station and as usual the best lots of fingerlings will be segregated until they mature. An exceptionally high percentage of these eggs hatched and, since they were taken from a stock of fish producing highly fertile eggs, it is a reasonable tentative assumption that this high fertility is a result of selection.

In the breeding experiments at the Leetown, W. Va., station eggs were taken from 38 pairs of selected brook trout, a part of which were select stock of the second generation. In an effort to obtain a strain of brook trout which will produce eggs better adapted to conditions at Leetown, stock is being selected at present on the basis of high fertility rather than of rapid growth, body symmetry or other characters. The present standard requirement for a select stock is a minimum of 70 percent reaching the eyed stage, an exceptionally high figure for brook-trout eggs at Leetown, the average being approximately 43 percent.

Breeding experiments have also been carried on with rainbow trout and with brown trout.

Nutrition studies.—Nutrition studies have been continued at the Cortland, N. Y., hatchery by Dr. C. M. McCay and A. V. Tunison. Three lines of research have been followed during the year: (1) Continuation of the study on growth of four species of trout fed similar diets, and maintained under similar conditions; (2) the determination of the amount of feed that should be fed per unit of weight to attain the most economical production; and (3) biochemical studies to determine the optimum amount of phosphorus and calcium needed by a growing trout. The four species used were: Lake trout (*Cristivomer namaycush*), brown trout (*Salmo fario*), rainbow trout (*Salmo irideus*), and brook trout (*Salvelinus fontinalis*).

The experiment to determine the relative ability of the species to convert feedstuffs into body tissues was continued through the 128th week. All four species were maintained under similar conditions and fed the same diet, consisting of two parts fresh beef liver and one part dry skim milk. The numbers were reduced from time to time to eliminate the factor of overcrowding. It was found that lake trout was the most efficient of the four species in the conversion

of feedstuffs into live body weight under the conditions of this experiment, while the brown trout seemed to be least efficient.

Two lots of brook trout were fed separate diets in the experiments to determine the most satisfactory amount of feed that will produce the most economical gain in weight. One diet consisted of equal parts, by weight, of beef liver and trimmed beef hearts; while the other contained in addition to these meats dried skim milk, cottonseed meal, and whitefish meal. The results of these experiments show clearly that (1) within certain ranges, the efficiency of feed utilization is inversely proportional to the quantity fed; (2) the utilization of dry feeds is much less efficient than that of raw meats, although the dry feeds are more economical in cost; and (3) young fry probably need 10 percent of their body weight in feed while older trout, up to a length of 3 inches, need only about 5 percent. Hatchery feed bills can be greatly reduced if a more effective method of using dry feedstuffs can be discovered.

Experiments were conducted to determine the amounts of calcium and phosphorus in the trout body, and the source of these mineral elements. There is good evidence to show that trout absorb calcium from the water even as early as the egg stage. In the egg and the sac fry stages phosphorus was found to be 6 to 8 times more abundant than calcium. But during the subsequent period of rapid growth, the calcium content of the body increases rapidly until finally in older fish it tends to exceed the phosphorus content.

Field investigations.—To test the common belief that rainbow trout will not long remain in the smaller streams in which they have been planted (at least in eastern streams), experimental plants of yearling rainbow trout were made in the fall of 1933 and also in 1934 under the direction of R. F. Lord. These plants were made in the South Branch of Cold River, a small mountain stream with an average volume of 10 to 12 cubic feet per second.

An attempt was then made to keep account of the number of fish caught, by the following procedure: Anglers were provided with blank forms on which they were requested to state the number of fish they caught, as well as certain other information. These they were asked to deposit in mail boxes set up for the purpose conveniently near common parking places. The mail boxes were painted a brilliant red to attract attention, and advertised by conspicuous signs which were posted along the stream calling attention to the fact that the Bureau of Fisheries was attempting to secure data on the number of fish taken annually from the stream as a guide for future stocking.

As recorded in a previous report, the results for a similar experiment in 1934 were unsatisfactory, only 87 fish being reported out of 700 fish planted the previous fall. This was a return of approximately 12 percent, but it is probable that only a small proportion of the anglers reported, and that the actual total catch of planted fish was much greater than that figure.

In the fall of 1934, 1,000 yearling rainbows were planted in the same stream. These fish were marked by removing the right pelvic fin to distinguish them from the fish planted a year previously, which had the left pelvic fin removed. The fish were well distributed along the stream, every effort being made to avoid too great a concentration in any area.

During the first month of the open season a fair degree of cooperation was obtained from anglers, 66 reports being left in the mail boxes. In June, however, only one report was filed, although it is known that fish were still being taken. A total of 290 fish were reported for the season, 11 of these being fish that had been planted in 1933.

Furnace Brook in Rutland County was the only stream operated as a test stream in 1935. It is a clear-water stream, more or less rocky, with a bottom that remains fairly stable. The test area was approximately 4 miles in length, and commenced just above a falls that stops practically all upstream movement of fish. The stream averages about 25 feet wide and is subject to heavy fishing throughout its length. Both brook and rainbow trout are established in the stream, but only brook trout have been planted in this area in recent years. It was stocked in September 1934 with 2,400 legal-size trout.

During the fishing season, May 1 to August 14, 1935, inclusive, 1,197 angling reports were secured. These show that the season's catch consisted of 8,589 legal trout, of which 5,647, or 66 percent, were brook trout and 2,942, or 34 percent, were rainbow trout. The average number of fish per fishing effort was 7.2.[7]

The outstanding fact revealed by this study is the tremendous amount of angling being done by today's fishermen; and it is evident that under such conditions good fishing can be maintained only by continual management. So valuable has this study proved itself that plans have been perfected to set aside four test streams during the 1936 fishing season.

Studies on Big Spring Creek, Va.—A study of the production of rainbow trout in relation to the number of fish planted and the abundance of natural food was continued under the direction of E. W. Surber in a 1-mile section, comprising approximately 1.65 acres of water area, of Big Spring Creek, near Leesburg, Va. During the season, 124 trout of legal size were taken with hook and line. The total weight of these fish was 57.47 pounds, a yield of 34.83 pounds per acre. This result compares favorably with those obtained in 1933 and 1934 when yields of 29.7 and 27.66 pounds per acre, respectively, were obtained.

Bottom samples were taken at monthly intervals, and the wet and dry weights of the organisms determined after they had been counted and identified. The average wet weight of bottom organisms for the year ending September 9, 1935, was 6.695 grams per square foot. The average dry weight of these samples was 1.321 grams. This is a material increase over the previous year, when there was an average wet weight of 5.047 grams and an average dry weight of 0.982 grams per square foot.

A total of 1,080 fingerling rainbow trout were planted in the fall of 1934 in Big Spring Creek. These fish were marked by removing the right ventral fin so that they could be distinguished from those produced by natural propagation. Sixty-five fish thus marked were recaptured—a return of 6.02 percent of the fish planted. While it

[7] "Fishing effort is the fishing done by 1 man during the course of 1 day, regardless of how long a period or how many times he fishes during the day.

thus appears that only a small percentage of the fish planted reached legal size, the results are much better than in the previous year, when only nine marked fish were recaptured.

COOPERATIVE WORK IN NATIONAL FORESTS

Under the terms of a cooperative agreement recently completed with the United States Forest Service the Bureau of Fisheries assumes responsibility for conducting research necessary for the development of a comprehensive program of fish management for waters of the national forests.

Owing to lack of funds the Bureau was unable to continue stream surveys in the national forests during the summer of 1935, and its activities in connection with stream improvement were confined to exercising technical supervision over the work carried on in this field by the Forest Service.

During the latter part of May a short field course for training men to plan and direct stream-improvement work was conducted by the Bureau and the Forest Service in the Pisgah National Forest, N. C. Early in June a similar training school was conducted in the Cache National Forest, Utah. At the close of these training courses the men were employed by the Forest Service to take charge of stream-improvement work in national forests throughout the country.

The stream-improvement work carried on during the last 2 years has been largely experimental, the ultimate aim being to determine to what extent this work can be relied upon to improve angling conditions. The results indicate that in streams notably lacking in pools and shelter much can be done to provide better living conditions for fish. In some cases it has been possible to provide additional spawning beds and to improve those already present, thus permitting a considerable increase in natural propagation.

In the average mountain stream dams in one form or another have been found to be more valuable on the whole than any other type of structure. Since such streams are often deficient in pools and are subject to the scouring action of frequent floods, structures are needed that will tend to retard erosion rather than accelerate it. Deflectors have also been used to advantage, but usually have proved most valuable when used in connection with dams to improve circulation in pools and to prevent deposits of silt and sand.

A considerable part of the stream-improvement work has consisted of the removal of obstructions of various kinds that interfered with the movements of fish. Other work has been the planting of trees, shrubs, and other vegetation to furnish shade and beautify the banks. It is evident that in many instances reforestation will do more to improve stream conditions than all other methods combined.

In view of the urgent need for further information on the value of stream improvements and on other means of improving fishing conditions in the national forests, arrangements were made for a number of experimental projects in this field. These projects, which are being carried on in cooperation with the Forest Service, and in some cases with State conservation agencies, are designed to throw more light on the more important factors concerned in fish management.

The most extensive project of this kind has been planned for the Pisgah Division of the Pisgah National Forest. This forest affords an exceptionally favorable opportunity for investigations of this nature, since it contains many excellent trout streams which are under the complete control of the Forest Service. It is proposed to use these streams for a demonstration of scientific stream management as a means of improving angling conditions. A rearing station is being constructed on the headwaters of the Davidson River, where fish required for stocking can be reared to the required size.

A similar arrangement was completed for the use of certain streams in the Big Levels Game Management Area in the George Washington National Forest. Work on these streams was started in August 1935.

California trout investigations.—Excellent progress has been made on the cooperative program, organized in 1932, with the California Division of Fish and Game. No radical changes were made this year in the field program, which consists of work along two major lines of effort: The Hot Creek brood-stock experiments and the coastal-stream steelhead studies. Dr. P. R. Needham is in general charge of the field program and in direct charge of the Hot Creek project, while A. C. Taft has supervision of the coastal-stream steelhead project. Two assistants, Leo Shapovalov and Leo Erkkila, are supplied by the State Division of Fish and Game.

Lack of funds prevented continuance of stream and lake surveys on the scale begun in 1934 with P. W. A. funds. However, brief biological surveys were made by staff members on Salton Sea, Bucks Lake, Lake Merced, and Lake Arrowhead, in California.

Studies on the steelhead of the coastal streams have continued and additional work has been undertaken on the Klamath River.

At Scott and Waddell Creeks, in Santa Cruz County, a census of the run is made each year in order to determine the basic facts in the life history of the steelhead and silver salmon, such as age, growth, migration, and the return from given escapements. At Scott Creek during the 1934–35 season the run was somewhat larger than during the previous 2 years and totaled 585 fish. Nearly 45 percent of the fish were grilse, and, judging from the number of marked fish among them, they were largely from the planting of the previous year. On February 12, 5,608 fish which had been reared at the hatchery ponds during the previous summer were released below the dam. Losses were very heavy in the ponds, due to an outbreak of furunculosis. Although this epidemic, if continued, may seriously hamper the work, the survivors are being marked and planted in an effort to determine if they and their progeny will show an increased resistance to the disease.

Judging from the number of silver salmon and steelhead trout taken at the Waddell weir during the two seasons in which it has been operated, the run of adult fish was somewhat greater during the past season. The number of steelhead migrants, however, was smaller, perhaps owing to the loss of adult fish from furunculosis during 1933–34. The downstream movement of cottoids was repeated at the same season as in 1933–34, but the run was greatly reduced in size.

On the Klamath River marked steelhead have been planted in Fall Creek and Beaver Creek, two moderate-sized tributaries of the upper river. During May 1935 an additional lot of 29,000 fish were marked

by the removal of both ventral fins and planted in the West Fork of Beaver Creek. This planting of marked fish was made with the dual purpose in view of comparing the more detailed findings made at Waddell Creek with the somewhat different conditions found on the Klamath, and of establishing an annual run of marked fish which would give some indication of the varying intensity of fishing in the main stream below.

In May the ponds at the Hot Creek station were drawn down and the survivors of the select lots of fingerlings that had been planted in the previous July and August were netted out, graded, and the best retained for brood-stock purposes. An average survival rate of 23.36 percent obtained after a period of approximately 9 months in the four natural ponds used. A total of 27,300 pedigreed trout weighing 717 pounds were planted in nearby waters from the Hot Creek ponds this year.

The number of select brood stock held for experimental breeding purposes now total 1,597 fish, representing five different strains of rainbow. The majority of these fish will reach spawning age in the fall and winter of 1936–37, when actual selective breeding tests will be started.

Remarkable growth rates have obtained in spring water at Hot Creek at 63° F. On natural foods, starting with fish between 2 and 3 inches long, growth averaged approximately half an inch per month. In a feeding experiment 100 rainbow averaging 5 inches in length were fed a diet of 30 percent liver (fresh weight), 35 percent salmon egg meal, and 35 percent abalone chips. Under the regime, growth averaged approximately 1 inch a month. Another lot of the same size and kind of fish held under identical conditions, but fed only pure shrimp collected from watercress beds grew on the average 0.82 inch per months. The experiments with both lots of fish were run for a period of 85 days. It required 3 pounds of the liver—salmon egg meal—abalone chips diet to produce a pound of trout at a cost of $0.28 per pound of trout raised. The cost of this diet was $0.084 per pound. It required 9.57 pounds of shrimp (wet weight) to produce a pound of trout in the shrimp fed lot.

Excellent returns were obtained from the Angora Lake planting experiment this year, 136 catches, yielding 809 trout, being recorded. Marked fish of the 1933 and 1935 plants combined formed 77 percent of the 809 caught in 1935. Only 23 percent of the catch were unmarked trout. No marked trout were caught prior to the 1935 fishing season. The average catch per angler in 1934 was 2.3 fish and in 1935, 5.9 fish.

A plant of 2,014 marked rainbow trout averaging 5.67 inches in length was made in Convict Lake on July 20, 1935. The object of this plant was the same as those made in Angora Lake; viz, to compare numbers actually taken by anglers with numbers planted. Another object was to test a new system of boat records from which the catch per unit of effort from year to year could be determined.

The results obtained are most promising. The catch per unit of effort [8] was determined as 0.21 fish per hour per angler. Boat fishermen filled out 106 catch-record blanks. Only 50 percent of the parties renting boats actually caught fish. For those taking trout

[8] Here "catch per unit of effort" is not the same as "catch per fishing effort" defined on p. 440.

the average catch per boat was 3.6 fish. The average length of the rental period was slightly over 4 hours. Of the 2,014 marked rainbows, 349 or 17 percent of the total plant were caught. By using the proportion of marked to unmarked rainbows caught, it is possible to estimate roughly the total rainbow population of Convict Lake. Catches of shore fishermen were likewise recorded; and trout caught both by this group of fishermen and persons fishing from boats totaled 848 fish. Of this number 25 percent were loch leven, 33 percent unmarked rainbow, and 41 percent marked rainbow of the 1935 plant. Approximately 76 percent of all fish taken were caught by shore fishermen while 24 percent were taken from boats. Boat fishermen caught larger fish hence more pounds than shore fishermen obtained, but they caught fewer fish. By determining the catch per unit of effort annually a definite measure of the trend of the fishery in the lake will be obtained. Thus, the effects of any system of management, stocking, or restrictions put into effect by fish and game authorities can be ascertained.

FISH DISEASES

As in previous years, the study of fish diseases was largely confined to investigations of epidemics at hatcheries and the development of better methods of control. The establishment of a pathological laboratory at Seattle, Wash., in charge of Dr. Frederic F. Fish has made it possible to devote more attention than formerly to disease problems in the intermountain region and the Pacific Coast States.

The major investigations of the West Coast Pathology Laboratory during the past year have been directed towards a reduction in the toll of salmon and trout taken by diseases in the hatcheries. As the presence or absence of disease largely determines the advantage of artificial over natural propagation, the work of this laboratory has been directed chiefly toward preventing diseases rather than attempting to develop new methods for treating them after they have appeared. The prophylaxis of fish diseases represents a practically unknown field, and many preliminary problems had to be satisfactorily solved before a suitable technique could be evolved. The method chosen for experimental disease prevention work was the routine application of a constant and weak concentration of a disinfectant to the running water supply of a hatchery trough for a uniform period of 1 hour at weekly intervals. This method, commonly known as "prolonged dipping", was favored because it involves a minimum amount of labor for its application, and does not necessitate the handling of the fish in any way. Consequently it solves the disease-control problem for the one-man hatchery.

Although it has been definitely demonstrated that at least certain parasitic diseases of trout may be prevented by routine prophylaxis, disease-prevention work is still in the experimental stage. The losses attending prophylaxis are materially lower than those occasioned by therapeutics. Attempts to cure epidemics of parasitic protozoa have invariably involved considerable losses of fish even though the treatments were carefully administered at the first indication of trouble. The disinfectants available for disease-prevention work are

many, and present efforts are directed towards the determination of the maximum concentration of each practicable disinfectant tolerated by trout, and the minimum disinfecting concentration effective against each type of pathogenic organism. The eventual goal of the disease prevention investigations is the development of a technique involving the use of some disinfectant, or combination of disinfectants, which may be applied under ordinary hatchery conditions with a minimum of effort and which will prevent the appearance of most, if not all, diseases of hatchery trout and salmon.

Another research project of this laboratory concerns the epidemiology of fish diseases—likewise a new field of endeavor. Through the generous cooperation of the Division of Fish Culture, daily loss records are kept on individual lots of fish by all hatcherymen in the intermountain and Pacific coast regions. An accurate loss record is thus available for every lot of fish from the time they are brought to a hatchery until they are finally liberated. Over a period of time, an analysis of these records should not only yield reliable information concerning the efficiency of individual hatcheries, but should likewise demonstrate many of the factors responsible for losses, and the exact effect of efforts to correct these factors. Such information should prove of great value in raising the efficiency of the entire system of artificial propagation of trout and salmon.

During the year, studies were undertaken on the relative sterilizing power of the various disinfectants commonly used at hatcheries. For such studies, a modified phenol coefficient technique was employed and a strain of *Bacterium salmonicida* was chosen as the test organism. It was indicated that any concentration of these disinfectants capable of killing *B. salmonicida* during an exposure of 1 hour was likewise fatal to fish life in the same period of time. A concentrated solution of calcium hypochlorite proved to be the most satisfactory disinfectant for sterilizing ponds not containing fish and for nets, dippers, and other hatchery utensils.

The more basic pathological studies on individual diseases of fish were continued during the year. A previously unrecognized type of gill disease, of similar pathology but different etiology than the bacterial gill disease common to eastern United States, was found affecting both trout and salmon at several western hatcheries. This disease was apparently of bacterial origin, and although several organisms were isolated in pure culture from infected gill tissue, suitable opportunity for experimental infections has not yet been available. Until such experiments are accomplished it is impossible to state which one, if any, of the cultivated organisms is responsible for the disease. This western variety of gill disease has failed to respond favorably to any known form of treatment. Apparently by the time the presence of this disease is realized, the host is so weakened through extensive tissue alteration that it is unable to withstand the additional rigors of treatment.

In addition to the definite long-term projects summarized above, numerous field trips have been made to assist the hatchery men with their disease problems.

A new disease known as "white mouth", affecting tropical fish in the Southern States, was found to be due to infection with *Bacillus*

columnaris. This organism, known to cause serious losses among bass, crappie, sunfish, etc., when they are handled in warm weather, has not previously been reported among aquarium fish. It affects tropical fish chiefly during shipment. Evidently as the result of injuries caused by bumping against the sides of the can, the lower jaw becomes infected, the infection advancing along the floor of the mouth until it reaches the gills. This bacterial growth forms a white felt-like mat from which the disease derives its name. The disease can be easily controlled in early stages by treatment with a dilute solution of copper sulphate or other disinfectant.

It is now evident that an attempt to eradicate furunculosis at the Leetown (W. Va.) experimental hatchery has been entirely successful. During the summer of 1934 several lots of brown and brook trout yearlings developed the disease. Immediately all fish in the infected lots were destroyed and the pools disinfected with chlorine gas. Inasmuch as no signs of furunculosis have appeared at this station since that time it is evident that the disease was completely eradicated. This case is of special interest since it demonstrates that, if taken in time before it has become established, furunculosis can be stamped out at a hatchery without a significant loss of fish.

The investigation into the causes of "blue-sac" were continued at the Leetown station by E. W. Surber. It was suggested that the trouble might be due to the high free carbon dioxide content of the hatchery water supply (about 44 parts per million). Accordingly a series of experiments was conducted to investigate the relation between the acid-base equilibrium and the health of trout. It was found that:

1. Raising the free carbon dioxide content of the water to 60.7—62.1 parts per million resulted in a decreased hatch, and an increase in the number of deformed fish.

2. Brook trout eggs in soft water can develop normally in relatively high concentrations of free carbon dioxide (39 p. p. m. at Ogletown, Pa., 42.03 p. p. m. at Lewistown, Md.).

3. Blue-sac was not nearly so evident in water neutralized with sodium hydroxide, but since the general effect of this chemical was otherwise so deleterious there appears to be no advantage in its use.

4. The addition of sufficient caustic soda to neutralize most of the free carbon dioxide in the water is injurious to brook trout eggs, reducing the hatched fry to about 28 percent or less of the original number.

5. Brook trout eggs are more sensitive to the chemical changes brought about by the addition of caustic soda than are rainbow eggs, which in earlier experiments were either unaffected or benefited by its addition.

The functions of the Disease Service were greatly expanded during the year, and a large number of specimens submitted by Federal, State, and commercial hatchery men were examined and diagnosed at both the Washington and Seattle laboratories. Although in most cases the service is limited to the examination and diagnosis of preserved material, it has been of great assistance in enabling fish culturists to adopt proper control measures before epidemics were so far advanced as to render such measures ineffective.

FISHERY INVESTIGATIONS IN INTERIOR WATERS

M. M. Ellis, *in charge*

POLLUTION STUDIES

The growing menace of pollution in the fresh waters of the United States by erosion, and by municipal and industrial wastes has been accepted fatalistically by many as inevitable because the basic facts, chemical, physical, and biological, concerning stream pollution generally have not been available. The menace is spreading not only throughout the various river systems but into the impounded waters as well, and threatens at various points the waters of the public domain and of the national playgrounds. Consequently remedial and corrective measures compatible with the interests of fisheries and with economic necessities have not been easy to define.

To meet this situation the Columbia (Mo.) field unit of the United States Bureau of Fisheries has been conducting for some time investigations to ascertain: (1) The natural conditions favorable for fish and other aquatic life in unpolluted waters, so that a polluted stream can be defined with fairness to all concerned; (2) the specific effects on fish and other aquatic life, and on the aquatic environment itself, of the various types of effluents which are being turned into the fresh waters of the United States.

Much effort has been given to devising suitable tests for the determination of the extent of stream pollution that could be applied practically in the field.

A set of water standards has been defined, based upon the results of thousands of tests and analyses made in all of the major river systems of the United States. The common variables in stream water; namely, dissolved gases, salts, turbidity, and ammonia are defined with reference to the limits constituting a suitable environment in which desirable fish can thrive. These standards provide a background for the study of stream pollution regardless of its source or extent.

Detailed biochemical, physiological, and pharmacological studies of over 40 types of effluents have been made, from which the specific effects of these effluents on fish and other aquatic life, as well as the reactions of these effluents with the stream water itself have been determined. From these studies it has been possible to make definite recommendations for practical remedial measures in various cases of stream pollution. As this work is continued more such applications can be made.

Mobile units, housed in autotrucks, have been perfected for the field study of stream pollution. These field laboratories make it possible to cover large distances rapidly, and to obtain at the source of pollution data supplementing the experimental tests conducted at the central laboratory at Columbia, Mo., and at the branch laboratories for trout studies at Bozeman, Mont., and for long-time tests on warm-water fishes at Fort Worth, Tex.

During the past year, in addition to the general work outlined above, specific pollution investigations have been made in Maine, Pennsylvania, West Virginia, Tennessee, South Carolina, Virginia, Montana, Idaho, Arizona, New Mexico, Texas, Oklahoma, and in the Mississippi Valley, through cooperation with the War Department,

the Department of the Interior, the Tennessee Valley Authority, various State organizations, and several industrial concerns.

The future work of this unit calls for advancing as rapidly as possible the detailed studies of the effluents themselves, as only through an understanding of the actions of these effluents on fish and other aquatic life can remedial measures be expected. Besides, new types of effluents are constantly appearing as new industrial developments are made.

The surveys of particular streams having specific pollution problems are to be furthered as rapidly as funds permit, as the work of this unit has by no means covered all of the types of existing stream pollution.

MUSSEL PROPAGATION

During the past year the long-time experiments on growing fresh-water mussels in restricted areas have been continued at Fort Worth, Tex. These experiments, which will tell their complete story only after several years of actual test under practical conditions such as are being maintained at Fort Worth, continue to give promising returns. It is interesting in this connection to note that similar efforts are being made with some success to raise oysters in crates and confined areas off the bottom in silt-laden water, utilizing methods similar to those employed at Fort Worth with fresh-water mussels.

INDEPENDENT ACTIVITIES OF THE FISHERIES BIOLOGICAL LABORATORIES

WOODS HOLE, MASS.

Owing to lack of funds, the Woods Hole laboratory was not maintained on an operating basis in 1935. Although facilities were utilized in connection with the oyster investigations reported upon elsewhere, no independent activities were possible.

This condition not only retards progress in the Bureau's fishery investigations, but also loses to the Bureau the advantage formerly gained from results obtained by independent investigators through use of the laboratory's facilities. Correction of this condition is urgent.

BEAUFORT, N. C.

Facilities for the study of marine-fishery problems of the South Atlantic region were provided throughout the year by the Beaufort laboratory under the direction of Dr. H. F. Prytherch. The chief investigations conducted here by the Bureau's staff, as reported in detail elsewhere, consisted of experiments and studies with reference to (1) the biology and control of the oyster drill, (2) the distribution and abundance of oyster pests in the coastal waters of Virginia, North Carolina, South Carolina, and Georgia, (3) a protozoan parasite of the oyster, (4) an improved method of handling oyster meats, (5) the development of the ovaries of the commercial shrimp, and (6) food of the commercial shrimp.

The laboratory serves as headquarters for oyster investigations in the South Atlantic and Gulf States, and has cooperated with the conservation departments of Virginia, North Carolina, South

Carolina, Georgia, Florida, and Mississippi in planning and directing extensive operations for the rehabilitation of public oyster beds in the respective States with funds provided by the Federal Emergency Relief Administration and Works Progress Administration. In North Carolina assistance was given to the N. C. E. R. A., and the conservation department in technological, statistical, and administrative matters pertaining to the formation of a cooperative fishermen's organization which began operation in October 1935.

Laboratory facilities for marine research have been provided for eight independent investigators from other institutions who were engaged in the following studies: Prof. H. V. Wilson, University of North Carolina, experimental-histological studies on the cellular structure of sponges; J. W. Culbertson, under supervision of Professor Wilson, on the breeding times of sponges; J. S. Denby, Brevard College, study of marine fauna and the ecology of a typical sand shoal; J. H. Pratt, Jr., Harvard Medical School, disposal of industrial and domestic trade wastes at Beaufort, N. C., and vicinity in relation to municipal supply and sea-food industries; Prof. Hoyt S. Hopkins, New York University, effect of reducing agents on oxidation of tissue in mollusks; Dr. F. G. Walton-Smith, Commonwealth Fund Fellowship, England, physiology of oyster larvae; Dr. Hugh S. Darby, Columbia University, development of the fiddler crab; R. S. Collie, North Carolina State Museum, collection and preparation of marine animals for exhibition.

Terrapin culture.—The propagation of diamond-back terrapin was continued at the Beaufort laboratory in cooperation with the Division of Fish Culture and yielded, in 1935, a total hatch of 13,245 young terrapin, which is the greatest annual production obtained in these operations. The highest previous record was that obtained during the preceeding year when a brood of 12,446 was produced in the five separate breeding pens. During August and September the newly hatched terrapin were collected from the protected egg beds and transferred to the large rearing house where they were given special care and feeding in order to get them in good condition before hibernation. During the winter months, or hibernating period, the young have been kept in a newly constructed outdoor pen located in one of the large terrapin pounds on the north side of the laboratory. The hibernating pen, having a length of 56 feet and a width of 10 feet was constructed with concrete walls and close fitting, movable wood covers so as to insure complete protection of the young against damage by rats and mice as occurred during the previous season. The distribution of the 1935 brood will be made during the spring of 1936 throughout the South Atlantic coastal waters in cooperation with the various State conservation departments.

ICHTHYOLOGICAL INVESTIGATIONS

Investigations in Panama.—Upon the request of Dr. Herbert C. Clark, director of the Gorgas Memorial Laboratory, Panama City, cooperative investigations with that laboratory were made in Panama. Dr. Samuel F. Hildebrand was detailed for the work by this Bureau. Largely because of the splendid cooperation offered by Dr. Clark and various Panama Canal officers, a comparatively

large area was covered and a large amount of work accomplished in the short time from January 26 to March 11.

Dr. Clark particularly desired to obtain an identified series of the more common local species of fishes for the laboratory collection, principally for use in determining the species from which parasites are obtained for study from time to time by the staff helminthologist, Dr. Aurel O. Foster. As many species as possible were collected and later identified in Washington. Representatives of 97 more or less common species have been sent to the Gorgas Memorial Laboratory. Many more species were obtained which require further study for exact determination. In the laboratory in Washington Dr. Hildebrand was assisted by Louella E. Cable.

The time chosen for the investigation was particularly auspicious because the Gatun Locks were dewatered, giving the investigators not only an opportunity to "gather" fish on the bottom, but also to see and study the fauna present in the locks. The two species of fish present in great abundance in the two lower levels of the locks were the "blue jack", *Caranx hippos*, and the "bony fish", *Elops saurus*. Other species present in these levels of the locks were the tarpon, several species of snappers, a few groupers, and a considerable variety of less common and smaller fish and minnows. The upper chamber of the locks, in which the water is quite fresh at all times, contained only a few large tarpons, a few marine mojarras, *Gerres plumieri*, a few anchovies, and several small fresh-water fishes.

It is often asked whether the locks are a passageway for fish. It is understood, of course, that strictly marine fishes, even though they should succeed in passing through the locks could not endure the fresh water of Lake Gatun. However, there are some species that are able to pass from salt to fresh water and vice versa without evil effects. Among these is the tarpon, now a regular inhabitant of Lake Gatun. It also occurs in Miraflores Lake, which it could reach only by passing through Culebra Cut and the locks at Pedro Miguel. A special effort was made to determine whether this fish breeds in one of these fresh-water lakes or adjacent arms and streams. However, no evidence indicating that breeding is taking place in fresh water was secured. It seems probable, therefore, that the locks are used as a passageway by the tarpon, and very probably by a few other species.

Upon the request of Col O. G. Brown, chief health officer of the Panama Canal, inspections were made of a large area of Gatun Lake, where a very profuse growth of Chara occurs, which at low water stages, as during the dry season, forms a very bothersome breeding area for mosquitoes. The situation, however, did not seem to be one that would lend itself to control by the use of fish.

Collections also were made at the Pearl Islands where local sportsmen maintain a fishing club, and where very excellent sport fishing is to be had. Small shore fishes were extremely scarce at the time the collections were made but a short distance offshore fishes were abundant and several species that apparently are new were obtained by trolling. Much more work is required to determine all the species secured there.

It was possible, also through the generosity of Dr. Clark and others to fly to the Rio Chiriqui Viejo near the Costa Rican border in southwestern Panama, to investigate the results of a plant of rainbow trout made by the Bureau of Fisheries in the upper stretches of this stream in 1925. It was found that the trout were abundant as had been reported by sportsmen. The temperature of the water during the several days spent on the stream in February at an elevation of about 6,000 feet varied from 54° F. in the morning to 57° F. in the late afternoon. Based on 45 digestive tracts examined, about 90 percent of the food injested by the trout consisted of caddisfly larvae and nymphs. The remaining food included beetle larvae and a few adults, mayfly larvae and nymphs, dragonfly larvae and nymphs, stonefly larvae and nymphs, net-veined midge larvae, a few midgefly larvae, a few adult terrestrial insects, and very few ostracods and amphipods.

MARINE FISHES OF THE GULF COAST

Systematic studies of the American fishes in general, and those of the Gulf coast in particular were continued by Isaac Ginsburg. Special attention was given to the revision of genera of the difficult families Pleuronectidae, Gobiidae, and Cyprinodontidae. These revisional studies should place the systematics of some of the more difficult marine families on a firm scientific foundation.

SILVER SPRINGS, FLA.

During the latter part of August, Dr. Samuel F. Hildebrand spent several days collecting fish in Silver Springs, Fla. Because of the clearness of the water it was found impracticable to collect with a seine during the day, as the fish were able to see the net and the collectors, and invariably retreated to a safe distance or depth. Consequently most of the collecting was done at night.

Altogether 25 species of fishes were obtained in Silver Springs. They consist of 2 species of gars, the bowfin, 2 species of catfish, the common fresh-water eel, a jack-pike or pickerel, the white mullet (a marine fish), 5 species of sunfish, the large-mouth black bass, and 11 species of minnows belonging to 5 different families. The collection, of course, is not exhaustive, but it very probably includes nearly all the regular residents.

Fishing is prohibited in the springs and large fish are fairly numerous, it being possible to see the entire population even to a depth as great as 50 or 60 feet, because of the clearness of the water. Small fish and minnows, however, are rather scarce. Evidently the springs have as large a population of predatory fishes, such as the bass, bowfin, catfish, gars, jack-pike, and sunfishes as can find sufficient food.

Lake Mattamuskeet.—Upon the request of the North Carolina Conservation Commission, Dr. Samuel F. Hildebrand was detailed to make an investigation of Lake Mattamuskeet to supplement another investigation made earlier in the year by other representatives of the Bureau (Messrs. Jackson, James, and Surver). The principal purpose of the investigation was to determine the comparative

abundance of large-mouth bass, and the status of the supply of food present for these fish. It had been alleged that the lake, which at one time was drained and then reflooded during recent years, was overpopulated, and that some of the fish should be removed.

It was found that although bass were numerous, food, such as minnows, young fish, and crustaceans, was scarce. It was found, furthermore, that the bass were mostly in an emaciated condition and were heavily parasitized, principally with the copepod of the genus *Lernaeocera*. Although adults were numerous, there were practically no young bass, indicating cannibalism. It was recommended that, although adult bass were numerous, the fish be left in the lake, partly because they were parasitized and partly because virtually no young bass were present. Under the circumstances, it seemed clear that with the limited amount of sport fishing permitted, the population would soon be reduced naturally until a "biological balance" would be reached, as has happened in other recently flooded areas previously observed by the investigator.

EASTERN TEXAS SURVEY

Dr. Hildebrand identified a collection of fish for R. T. Richey of College Station, Tex. The specimens were collected in eastern Texas, in connection with a survey made by Mr. Richey for the Game, Fish and Oyster Commission of Texas. The identifications are to be used in a report on the survey.

OTHER COLLECTIONS

In connection with the study of pollution of inland waters, Dr. M. M. Ellis made collections of 452 specimens of small and young fishes. The specimens were taken in many different sections of the United States, from Maine to South Carolina and from Montana to New Mexico. Dr. Hildebrand, assisted by Louella E. Cable, identified 69 species in the collections.

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